A34

The Kent Incorporated Society for Promoting Experiments in Horticulture

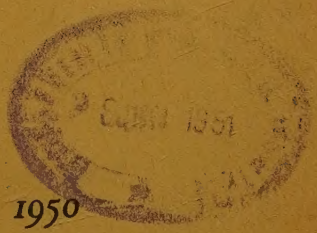
ANNUAL REPORT

1950

EAST MALLING RESEARCH STATION

Near MAIDSTONE

KENT



1st October, 1949 to 30th September, 1950

Price 10/- post free
Great Britain only
Overseas postage extra
Price U.S.A. $1·60

Published
June, 1951

CHURCH FIELDS NOS. 1-8. VIEW OF NEW STAFF HOUSES PROVIDED BY THE MINISTRY OF AGRICULTURE AND THE EAST MALLING RESEARCH STATION ASSOCIATION, 1950.

[frontispiece

A34

THE KENT INCORPORATED SOCIETY
FOR PROMOTING EXPERIMENTS IN
HORTICULTURE

ANNUAL REPORT

(THIRTY-EIGHTH YEAR)

1950

EAST MALLING
RESEARCH STATION

Near MAIDSTONE

KENT

1st October, 1949 to 30th September, 1950

Published June, 1951

The correct abbreviation of the title of this Report is :—
Rep. E. Malling Res. Sta. for 1950 (1951).

PRINTED IN GREAT BRITAIN BY HEADLEY BROTHERS LTD
109 KINGSWAY LONDON WC2 AND ASHFORD KENT

CONTENTS

PAGE

GOVERNING MEMBERS OF THE SOCIETY 5
MEMBERS OF THE EXECUTIVE COMMITTEE 7
STAFF 8
THE COMMONWEALTH BUREAU OF HORTICULTURE AND PLANTATION CROPS 13
NATIONAL AGRICULTURAL ADVISORY SERVICE 13
FOREWORD 14

Part I

THE EXPERIMENTAL FARM

TOP FRUITS 15
SMALL FRUITS 16
FRUIT MARKETING 17
FRESH PLANTINGS AND GRUBBINGS 17
ROUTINE SPRAYING PROGRAMME 18
ARABLE CROPS 18
EXPERIMENTAL NURSERIES 19

Part II

GENERAL REVIEW OF RESEARCH WORK, WITH LISTS OF PAPERS PUBLISHED DURING THE YEAR

I. POMOLOGY 21
II. STATISTICS AND RECORDS 28
III. PLANT PHYSIOLOGY 30
IV. BIOCHEMISTRY 34
V. PLANT PATHOLOGY 38
VI. ENTOMOLOGY 42
VII. PLANT PROTECTIVE CHEMISTRY 44
VIII. SCIENTIFIC LIAISON SECTION 48
A.R.C. SCOTTISH RASPBERRY INVESTIGATION 50

Part III

RESEARCH REPORTS AND REVIEWS

AMOS MEMORIAL LECTURE

The fruit tree and its environment. SIR EDWARD SALISBURY 53

POMOLOGY

The effect of netting and hessian anti-frost screens and of brick walls on air temperatures. W. S. ROGERS and A. BERYL BEAKBANE 60
The effect of certain growth-promoting substances upon frost-damaged apple flowers. IRENA MODLIBOWSKA 65
The grafting of very young apple seedlings. R. J. GARNER 71
The use of growth substances to widen crotch angles. A. P. PRESTON and H. W. B. BARLOW 76
Walnut varieties. ELIZABETH M. GLENN 80
A progress report on experiments with rabbit repellents. E. G. COKER 87
Weather conditions during 1950. A. P. PRESTON 90

STATISTICS

The estimation of fruit size of cherries by sampling methods. J. TAYLOR 93
Statistical studies on strawberry crop and vigour measurements. J. TAYLOR 100

PAGE

PLANT PHYSIOLOGY

Use of sprays to control fruit drop. VI. Rain and the control of pre-harvest drop in Sunset apples. H. W. B. BARLOW 108
Use of sprays to control fruit drop. VII. Effect of season and date of spraying on control of June drop in Cox's Orange Pippin. M. C. VYVYAN and G. F. TROWELL .. 111
Aspects of rootstock propagation. II. The development of the concentrated dip method of treating hardwood cuttings with growth substances. E. S. J. HATCHER and R. J. GARNER 116

BIOCHEMISTRY

A new and rapid method for estimating small quantities of calcium in plant material. A preliminary note. A. C. MASON 122
The estimation of iron in plant material. A. C. MASON 124

PLANT PATHOLOGY

Raspberry virus diseases : a survey of recent work. C. H. CADMAN and R. V. HARRIS 127
Brown Rot of apples : note on infection associated with hail bruises and lenticels. M. H. MOORE 131
The influence of rootstock on spray damage in apple. A. P. PRESTON, M. H. MOORE and MARGERY BENNETT 132
Black Rot and Leaf Spot of apple due to *Physalospora obtusa* (Schw.) Cooke. J. E. CROSSE and MARGERY BENNETT 137
The treatment of hop seed to improve germination. J. PAINE 139

ENTOMOLOGY

Notes on some interesting insects observed in 1950. A. M. MASSEE 141
A method for the estimation of insect populations on fruit trees. ELSIE COLLYER 148
Damage to apple leaves by the Fruit Tree Red Spider Mite, *Metatetranychus ulmi* (Koch). CATHERINE A. BLAIR 152
Observations on the dispersal of the Fruit Tree Red Spider Mite, *Metatetranychus ulmi* (Koch). GRETL MARLÉ 155

PLANT PROTECTIVE CHEMISTRY

Trials of zinc fluoroarsensate against Codling Moth, *Cydia pomonella*, L. A. H. M. KIRBY 160
Laboratory experiments on the toxicity of potential acaricides. A. H. M. KIRBY and K. S. MCKINLAY 164
The fungistatic activity of certain organophosphorus insecticides. A. H. M. KIRBY and E. L. FRICK 172
Experiments on increasing the penetration of ovicides and insecticides. K. S. MCKINLAY, A. H. M. KIRBY and M. ALLEN 177

HOPS

The classification of hop varieties according to their ease of picking. F. H. BEARD .. 187
Propagation trials with hops. VII. Number and size of sets produced from strap-cuts of certain varieties. F. H. BEARD 190

Part IV
BULLETINS FOR FRUITGROWERS

Research on fruit tree rootstocks. T. N. HOBLYN 193
Mechanical aids to nursery work. F. H. VILLIERS and T. V. DIXON 201
Raspberries in Scotland. C. H. CADMAN and C. A. WOOD 203
Virus diseases of sweet cherries. A. F. POSNETTE 209
The Raspberry Cane Midge and its control. R. S. PITCHER 211
Chemicals for the control of Apple Sawfly. A. H. M. KIRBY 213
An important new type of wetter. A. H. M. Kirby 214

GOVERNING MEMBERS OF THE SOCIETY

Appointed by the Ministry of Agriculture:

Dr. H. V. TAYLOR, C.B.E., Preston Grange, Barnet Road, Potters Bar, Middlesex.

Appointed by the Kent County Council:

Sir EDWARD HARDY, Boughton Court, Ashford, Kent.

Dr. OTTO SHAW, J.P., East Sutton, Maidstone, Kent.

T. E. WIMSHURST, Esq., Tibbs Court, Brenchley, Kent.

Appointed by the Surrey County Council:

T. HILLING, Esq., " Prestons ", Chobham, Surrey.

Appointed by the East Sussex County Council:

E. S. ATTRELL, Esq., Warren Fruit Farm, North Common, Chailey, Sussex.

Appointed by the West Sussex County Council:

W. FOWLE, Esq., Costrong Farm, Kirdford, near Billingshurst, Sussex.

Appointed by the Council of the Senate of the University of Cambridge:

Professor F. T. BROOKS, C.B.E., M.A., F.R.S., 31 Tenison Avenue, Cambridge.

Appointed by the Senate of the University of London:

Professor WM. BROWN, D.Sc., F.R.S., Imperial College of Science and Technology, South Kensington, London, S.W.7.

Appointed by the University of Bristol:

Professor T. WALLACE, C.B.E., M.C., D.Sc., F.R.I.C., The Research Station, Long Ashton, near Bristol.

Appointed by the Governing Body of the Imperial College of Science and Technology:

Professor V. H. BLACKMAN, Sc.D., F.R.S., 17 Berkeley Place, Wimbledon, London, S.W.19.

Appointed by the Council of the Royal Society:

Dr. E. J. MASKELL, F.R.S., The Botany School, Cambridge.

Appointed by the Governors of Wye College, Kent:

B. S. FURNEAUX, Esq., M.Sc., 94 Warwick Park, Tunbridge Wells, Kent.
D. SKILBECK, Esq., M.A., Wye College, Wye, Kent.

Appointed by the Research and Advisory Committee of Wye College, Kent:

Professor H. W. MILES, D.Sc., Ph.D., Wye College, Wye, Kent.

Appointed by the Council of John Innes Horticultural Institution:

M. B. CRANE, Esq., V.M.H., F.R.S., John Innes Horticultural Institution, Bayfordbury, Hertford, Herts.

Appointed by the Council of the Royal Horticultural Society:

F. A. SECRETT, Esq., C.B.E., F.L.S., V.M.H., Bell Farm, Felcott Road, Walton-on-Thames, Surrey.

Appointed by the Council of the Institute of Brewing:

M. V. COURAGE, Esq., Anchor Brewhouse, Horselydown, London, S.E.1.

Appointed by the Research Fund Committee of the Institute of Brewing:

G. T. COOK, Esq., Lulworth, Queen's Avenue, Maidstone, Kent.

Appointed by the National Farmers' Union (Central Council, London):

E. U. BLOOR, Esq., Tudor Grange, Nettlestead, Ipswich, Suffolk.
G. E. TUKER, Esq., Thorn Cottage, Danbury, Essex.

Appointed by the National Farmers' Union (Kent Branch):

W. ALEXANDER, Esq., M.B.E., Home Farm, Eynsford, Kent.
ALFRED DAY, Esq., O.B.E., J.P., St. Aubyns, Sutton Valence, Kent.
S. R. DIXON, Esq., J.P., Cambridge, Teynham, Sittingbourne, Kent.
W. T. EDMONDS, Esq., Allington Farm, Maidstone, Kent.
E. W. GASKAIN, Esq., Rhode Court, Selling, near Faversham, Kent.
E. BRUCE GIBSON, Esq., Lumbersland, Birchwood, Wilmington, Dartford, Kent.
C. T. MILLER, Esq., Wested Farm, Swanley, Kent.
D. J. MOOR, Esq., Nichol Farm, Teynham, Sittingbourne, Kent.
J. W. S. MOUNT, Esq., Little Barton, Canterbury, Kent.
T. NEAME, Esq., Macknade, Faversham, Kent.
J. F. TOWNER, Esq., Salts Farm, Loose, near Maidstone, Kent.
W. RODNEY WILSON, Esq., Mount Ephraim, Cranbrook, Kent.

Appointed by the Council of the Horticultural Trades' Association:

L. J. COOK, Esq., A.H.R.H.S., 7 Drapers Road, Enfield, Middlesex.

Appointed by the East Malling Research Station Association:

W. P. SEABROOK, Esq., St. Barnabas, Frinton-on-Sea, Essex.
R. D. WICKHAM, Esq., Gate House Farm, Brenchley, Kent.

Appointed by East Malling Research Station:

F. R. TUBBS, Esq., M.Sc., Ph.D.(Lond.), A.R.C.S., D.I.C., F.L.S.

Appointed by the Staff Council of East Malling Research Station:

W. G. KEYWORTH, Esq., Ph.D.(Lond.), A.R.C.S., D.I.C. (*Resigned September*, 1950.)
R. J. GARNER, Esq., N.D.H., Dip.Hort.Sci.(Reading). (*Appointed September*, 1950.)

MEMBERS OF THE EXECUTIVE COMMITTEE

(Governing Members elected at the General Meeting, September, 1948)

Professor V. H. BLACKMAN, Sc.D., F.R.S. (Vice-Chairman).
E. U. BLOOR, Esq.
Professor F. T. BROOKS, C.B.E., M.A., F.R.S.
Professor WM. BROWN, D.Sc., F.R.S.
G. T. COOK, Esq.
L. J. COOK, Esq., A.H.R.H.S.
M. B. CRANE, Esq., V.M.H., F.R.S.
ALFRED DAY, Esq., O.B.E., J.P.
S. R. DIXON, Esq., J.P.
W. T. EDMONDS, Esq.
W. FOWLE, Esq.
B. S. FURNEAUX, Esq., M.Sc.
Sir EDWARD HARDY.
J. W. S. MOUNT, Esq.
T. NEAME, Esq. (Chairman).
W. P. SEABROOK, Esq.
J. F. TOWNER, Esq.
G. E. TUKER, Esq.
Professor T. WALLACE, C.B.E., M.C., D.Sc., F.R.I.C.

The Director:

F. R. TUBBS, Esq., M.Sc., Ph.D.(Lond.), A.R.C.S., D.I.C., F.L.S.

The Representative of the Staff Council:

W. G. KEYWORTH, Esq., Ph.D.(Lond.), A.R.C.S., D.I.C. (*Resigned September*, 1950.)
R. J. GARNER, Esq., N.D.H., Dip.Hort.Sci.(Reading). (*Appointed September*, 1950.)

Co-opted Members:

Professor F. G. GREGORY, D.Sc., F.R.S., Imperial College of Science and Technology, South Kensington, S.W.7.

Sir EDWARD SALISBURY, C.B.E., D.Sc., V.P.R.S., 49 Kew Green, Kew, Surrey.

Lieut.-Colonel Sir ALBERT STERN, K.B.E., C.M.G., M.A., Barham Court, Maidstone, Kent.

Captain R. WELLINGTON, M.C., Colescus, Gorran Haven, St. Austell, Cornwall.

STAFF

(1ST OCTOBER, 1950)

Director: F. R. TUBBS,* M.Sc.(Lond.), Ph.D.(Lond.), D.I.C., A.R.C.S., F.L.S.
Assistant to Director: T. N. HOBLYN,* Hort.Dip.(Wye).

Pomology:

W. S. ROGERS,* M.A.(Cantab.), D.Sc.(Lond.), Dip.Hort.(Cantab.), A.Inst.P.
Miss A. B. BEAKBANE, Ph.D.(Lond.), N.D.H.
N. H. GRUBB, M.S.A.(Cornell). *Part-time.*
R. J. GARNER, N.D.H., Dip.Hort.Sci.(Reading).
D. W. P. GREENHAM, M.A.(Cantab.).
H. M. TYDEMAN, *Plant Breeding.*
Miss E. M. GLENN, B.Sc.(Lond.), *Field Records.*
Miss I. MODLIBOWSKA, Ph.D.(Lond.).
A. P. PRESTON, N.D.H.(Hons.).
Miss E. C. THOMPSON.
Miss B. G. MOSSE, B.Sc.(Lond.), Dip.Hort.(Swanley), *Histological Investigations.*
Miss J. M. PATON, Hort.Dip.(E. of Scotland), *Field Records.*
Miss D. J. WILSON, B.Sc.Hort.(Reading), *Field Records.*
Miss M. H. E. DAVIES, B.Sc.(Lond.).†
Miss C. P. NICOLL, B.Sc.Hort.(Reading).
MISS N. WALLICK, B.S.A.(Brit. Columbia). (*Resigned July*, 1950.)
J. P. RUXTON, M.A.(Oxon). (*Appointed September*, 1950.)
J. E. GOODE, B.Sc.(Birmingham). (*Appointed July*, 1950.)
C. H. W. SLATER.
Miss M. J. TAYLOR, B.Sc.Hort.(Reading). (*Appointed November*, 1949.)

Assistants (Scientific):

Miss E. C. M. ASHDOWN.
Miss J. BURTON.
Miss S. J. COGGER.
Miss P. HARRIS.
Miss G. P. R. HILLS. (*Appointed April*, 1950.)
Miss F. M. HODGES.
Miss M. TOPLEY. (*Appointed April*, 1950.)
Miss E. IRONMONGER. (*Resigned January*, 1950.)
D. G. L. HOOPER.

Statistics:

T. N. HOBLYN.*
S. C. PEARCE, Ph.D.(Lond.).
J. TAYLOR, M.A.(Cantab.). (*Resigned September*, 1950.)
Miss J. M. S. THOM, *Biometric Studies.* (*Resigned August*, 1950.)
G. F. W. BUCKLAND, B.A., Dip.Agric.(Cantab.), *Biometric Studies.* (*Appointed September*, 1950.)

* Recognized Teacher of the University of London.
† Appointed under special grant from Agricultural Research Council.

Assistants (*Scientific*) :

Miss V. V. Fry.
Miss L. V. Stickings. (*Appointed September*, 1950.)

Plant Physiology: M. C. Vyvyan,* M.A.(Cantab.), D.Sc.(Lond.).
Miss M. R. Rawes.
G. F. Trowell.

Assistants (*Scientific*) :

Miss J. G. Smith.
R. W. Love.

Members of Staff of the Imperial College of Science and Technology working in collaboration with the Physiology Section :

E. S. J. Hatcher, Ph.D.(Bristol).
H. W. B. Barlow, B.Sc.(Edin.).
C. R. Hancock, B.Sc.(Bristol).
F. W. M. Llewelyn, B.Sc.(Lond.), A.R.C.S.

Assistants (*Scientific*) :

B. F. J. Barrett.
W. R. Marchant.

Biochemistry: W. A. Roach,* D.Sc.(Lond.), A.R.C.S., D.I.C., A.R.I.C.
A. E. Bradfield, D.Sc.(Wales), Ph.D.(Wales), *Organic Chemist.*
S. G. Thompson, M.C., T.D., M.A.(Oxon).
A. C. Mason, B.Sc.(Lond.), F.R.I.C., *Physical Chemist.*
F. H. Vanstone, Ph.D.(Wales), A.Inst.P., *Physicist.*
A. E. Flood, M.A.(Cantab.), Ph.D.(Manc.), *Organic Chemist.*
H. J. Philcox.
Miss A. V. Delap, B.A., B.Sc.(Dublin), *Botanist.*
Miss E. M. Ford, B.Sc.(Lond.), A.R.C.S., *Assistant Botanist.* (*Appointed May*, 1950.)

Special Assistant :

Miss M. E. Bunyard, A.R.R.C.

Assistants (*Scientific*) :

H. Hutchins.
Miss B. M. Kidwell.
Mrs. R. D. Souter (*née* Miss M. Saunders).
R. Neve.
E. C. Wills.
Miss F. M. Woolgar.
Miss S. M. Lloyd.
Miss A. J. White. (*Resigned July*, 1950.)
Miss M. M. Acott. (*Resigned July*, 1950.)
Miss C. M. Bennett. (*Resigned March*, 1950.)
Miss K. O. Strowgler. (*Appointed September*, 1950.)
Miss M. E. Jenner. (*Appointed October*, 1950.)
Miss E. M. Price. (*Appointed October*, 1950.)

Members of Staff of the Imperial College of Science and Technology working in collaboration with the Biochemistry Section :

B. D. Bolas,* D.Sc.(Lond.), D.I.C.
H. C. Ruck, B.Sc.Hort.(Reading).

Assistants (*Scientific*) :

Miss C. C. Macnamara.
Miss B. Milton.

Plant Pathology: R. V. HARRIS,* D.Sc.(Lond.), A.R.C.S., D.I.C.
M. H. MOORE, M.Sc.(Reading), Ph.D.(Lond.), Dip.Hort.Sci. (Reading), *Plant Pathologist.*
W. G. KEYWORTH, Ph.D.(Lond.), A.R.C.S., D.I.C., *Plant Pathologist.*
A. F. POSNETTE, M.A.(Cantab.), A.I.C.T.A., *Virologist.*
J. PAINE, B.Sc.(Lond.), A.R.C.S., A.I.C.T.A., *Virologist.*
J. E. CROSSE, B.Sc.(Birmingham), *Mycologist and Bacteriologist.*
Miss M. BENNETT, B.Sc.Hort.(Lond.), Dip.Hort.(Swanley), *Field Trials ; also attached Entomology and Plant Protective Chemistry.*
P. J. ORMEROD, B.A.Agric.(Cantab.), *Field Trials, Hops.*
A. KOZLOWSKI, Ph.D.(Lwow), *Soilborne Diseases.*
Miss J. L. SMITH, B.Sc.(Glasgow). (*Resigned January*, 1950.)
D. S. KIRKHAM, B.Sc.(Lond.), *Bio-assay of Fungicides, attached to Plant Protective Chemistry.*
Miss P. M. GOODE, B.Sc.Agric.(Dunelm).
R. CROPLEY, Dip.Hort.(Reading).†
P. W. TALBOYS, B.Sc.(Lond.), Ph.D.(Lond.), D.I.C. (*Appointed February*, 1950.)

Assistants (Scientific) :
R. D. SOUTER.
Miss B. I. FLEET.
Miss M. M. JOYCE.
Miss S. SQUIRES.

Entomology: A. M. MASSEE,* D.Sc.(Lond.), F.R.E.S.
G. H. L. DICKER, Ph.D.(Lond.), A.R.C.S.
M. D. AUSTIN, F.R.E.S., *Red Spider Investigations in Essex.*
R. S. PITCHER, Ph.D.(Lond.), Dip.Agric.(Wye), Dip.Ento.(Wye), *Eelworm and Gall Midges.*
K. S. MCKINLAY, B.Sc.(Lond.), *Bio-assay of Insecticides attached to Plant Protective Chemistry.* (*Resigned July*, 1950.)
Miss D. E. GRIFFIN, B.Sc.(Lond.), A.R.C.S., *Bio-assay of Insecticides attached to Plant Protective Chemistry.* (*Appointed September*, 1950.)
Miss E. M. COLLYER, Ph.D.(Lond.), *Beneficial Insects of Fruit.*
Miss J. R. GROVES, B.Sc.Hort.(Reading), *Codling Moth.*
J. B. BRIGGS, B.Sc.Hort.(Reading). (*Appointed October*, 1949.)

Assistants (Scientific) :
E. F. SOUTER.
Miss H. MAY. (*Resigned September*, 1950.)
Miss S. O. PHILCOX. (*Appointed September*, 1950.)

Plant Protective Chemistry: A. H. M. KIRBY, M.Sc.(Lond.), Ph.D.(Lond.), A.R.I.C.
Miss B. S. WINTON, B.A.(Cantab.). (*Resigned January*, 1950.)
M. ALLEN, B.Sc.(Lond.).
R. G. GAMBRILL.

Miss V. P. J. Clarke, B.Sc.(Lond.). (*Appointed November*, 1949. *Resigned March*, 1950.)
E. L. Frick, B.Sc.Agric.(Wales). (*Appointed April*, 1950.)
L. J. Puleston. (*Resigned July*, 1950.)
Miss W. M. Phillips. (*Appointed September*, 1950.)

For Biological Assistants, see D. S. Kirkham, *Plant Pathology*, K. S. McKinlay *and* Miss D. E. Griffin, *Entomology Sections.*

Assistants (*Scientific*) *:*

Miss V. M. Drew.
P. Abery. (*Resigned September*, 1949.)
S. R. B. Solly. (*Appointed November*, 1949.)
Miss J. I. Brackenbury. (*Appointed April*, 1950.)
Miss J. Richardson. (*Appointed October*, 1950.)

Scottish Raspberry Investigation: *Headquarters—University College, Dundee.*
R. V. Harris,* *Head of Investigation.*
C. H. Cadman, B.Sc.(Liv.), Ph.D.(Edin.), F.R.S.E.,† *Plant Pathologist.* (*In charge.*)
C. A. Wood, Ph.D.(Wales),† *Pomologist.*
R. J. Rose.†

Clerical Assistant :

Mrs. A. S. Coull,† *Part-time.*

Assistants (*Scientific*) *:*

R. W. Reid.†
H. A. Bissett.† (*Resigned February*, 1950.)
P. H. Racionzer.†

Scientific Liaison: H. B. S. Montgomery, B.A.(Dublin), Ph.D.(Lond.), D.I.C.
A. C. Painter, O.B.E.
J. H. Walker, B.Sc.Agric.(Reading).
E. G. Coker, B.Sc.Hort.(Lond.). (*Appointed January*, 1950.)

Clerical Assistant :

Miss M. E. Emm.

Assistants (*Scientific*) *:*

Miss S. D. J. Humphreys. (*Resigned December*, 1949.)
Miss J. C. Irving. (*Appointed January*, 1950.)

Meteorological Records : A. P. Preston.
G. F. Trowell.

Librarian : S. R. Ball, B.A.(Lond.), F.L.A.

Photographer : E. Yoxall Jones.

FARM STAFF.

Farm Supervisor: F. H. VILLIERS, M.Sc.Agric.Econ., B.Sc.Agric.(Reading), N.D.A.

Assistant Plantations Officer: Miss B. F. SEYMOUR.

Experimental Nurseries: T. V. DIXON.

Experimental Greenhouses: M. M. MACNEILL, B.Sc.Hort.(Wye). (*Appointed July*, 1950.)
A. TIDY.

Workshops: G. WELLER.
K. W. G. BUNYARD. *Laboratory Instrument Mechanic.*

ADMINISTRATION.

Secretary: C. T. ROYLE, M.C.

Assistant to the Secretary: T. R. LITTLEHALES. (*Appointed January*, 1950.)

Book-keeper: P. R. WOOD.

Director's Personal Secretary: Miss L. M. READ.

Clerical Staff: Miss J. M. COY, Miss L. MIDGLEY (*Resigned August*, 1950), Miss J. D. MARTIN, Miss J. M. PARSONS, Miss L. SHERRATT, Miss P. M. RAYFIELD, Miss R. M. WICKHAM, Miss I. CROSS, Mrs. F. J. FITNESS, Miss D. M. ANSELL, Miss M. E. Wedgbury, Miss P. H. WESTACOTT, Miss D. A. JESSUP (*Resigned January*, 1950), Miss M. V. RELF (*Resigned April*, 1950), Miss D. CLEGG (*Appointed January*, 1950), Miss I. BELL (*Appointed April*, 1950), Miss P. RAYFIELD (*Appointed June*, 1950), Miss J. BATES (*Appointed July*, 1950), Miss K. D. APPS (*Appointed August*, 1950).

VISITORS.

Tours of the Station are arranged by appointment on Tuesday and Thursday afternoons. Visitors with special interests are received by appointment on the mornings of these days and may then join the general tour later if they wish. Wednesdays and Fridays are reserved for visiting research workers who also should make an appointment to ensure that a useful programme for the visit can be prepared.

All visitors wishing to see the work of the Station should go to the Enquiry Office at the Research Laboratories.

Visitors coming by road should take the turning to East Malling, opposite "The Bull", Larkfield, on the main London-Maidstone road. The entrance gate to the Research Station is on the left, opposite the "King and Queen" in East Malling.

Bus Service: From Maidstone by the Maidstone and District Motor Services Limited, every 20 minutes from Maidstone to East Malling.

Passenger Station: EAST MALLING HALT (British Railways, Southern Region).

Goods Station: Aylesford (British Railways, Southern Region).

Correspondence: All correspondence should be addressed to the East Malling Research Station, near Maidstone, Kent.

Telephone: Aylesford 7294 (3 lines). *Telegrams:* Research, East Malling.

THE COMMONWEALTH BUREAU OF HORTICULTURE AND PLANTATION CROPS

Accommodated at Bradbourne, the Administrative Headquarters of the East Malling Research Station.

STAFF.

Director: D. Akenhead, O.B.E., M.A.(Oxon), B.Sc.Agric.(Lond.).

Consultant Director: F. R. Tubbs, M.Sc.(Lond.), Ph.D.(Lond.), D.I.C., A.R.C.S., F.L.S.

Assistant Director: A. G. G. Hill, B.A., Agr.B.(Dublin), B.Sc.(N.U.I.), A.R.C.Sc.(I). (*Resigned November*, 1949.)
G. K. Argles, Dip.Hort.(Wye), A.I.C.T.A. (*Appointed March*, 1950.)

Assistants: H. Wormald, D.Sc.(Lond.), A.R.C.S., D.I.C.
V. H. Goldschmidt, Ph.D.
Miss P. J. Rowe-Dutton, B.Sc.Hort.(Lond.).
Mrs. E. Ulyatt, Dip.Hort.(Eisgrub.) (*Appointed May*, 1950.)

Clerical Staff: Miss M. B. Rogers, Miss M. M. Durling, Miss J. E. Morrison.

NATIONAL AGRICULTURAL ADVISORY SERVICE

Accommodated at Bradbourne, the Administrative Headquarters of the East Malling Research Station.

Telephone: Aylesford 7278.

PROVINCIAL ADVISORY OFFICER—FRUIT, SOUTH-EASTERN PROVINCE
W. G. Kent, N.D.H.

Clerical Assistant: Mrs. D. B. Dupuy. (*Resigned September*, 1950.)

FOREWORD

This year both the Administrative Report and the Annual Report cover the full financial year from 1st October 1949, to 30th September 1950.

Part I contains, as usual, details of the working of the Experimental Farm during the year. The accounts of investigations in progress in the various Sections are given in Part II, and will be found to reflect the greater volume of work in hand following upon the increases in staff in recent years. Part III consists of research reports and reviews, covering a wide range of subjects, while Growers' Bulletins in less technical language will be found in Part IV.

The text of the third Amos Memorial Lecture will be found in Part III. This was delivered by Sir Edward Salisbury, the Vice-President of the Royal Society, on 26th October, 1950, before an audience of over three hundred. This year, to mark the associations of Jesse Amos and of East Malling Research Station with the College, the Lecture was given at Swanley Hall, Wye College, by kind permission of the Principal.

The widening of research at East Malling offers increasing opportunities for collaboration with other scientists, both at home and overseas, who are working upon allied problems. Such collaboration is a valued feature of the work of the Station, and is dealt with in detail in the Administrative Report. Here it must suffice to record grateful acknowledgement to all those who have assisted the progress of the work during the year.

Part I

THE EXPERIMENTAL FARM

By F. H. VILLIERS with a contribution from T. V. DIXON

In contrast to the two previous years, fruitgrowers had little to complain of as regards the weather in 1950. Most areas escaped damaging spring frosts and, although conditions at time of pollination were far from ideal, in general both top and soft fruits bore satisfactory crops. The frequent summer showers were a welcome change from the scorching heat of 1949, and growing conditions generally were good throughout. Pears were in an " off " year in many districts and plum crops also were rather disappointing, but on the other hand crops of soft fruits were, on the whole, somewhat above average in spite of damage caused by a fall of snow late in April. Blossoming of most fruits was a little later than usual, but picking dates did not vary much from the average of recent years.

Experimental orchards.—Top fruits.

Apples.—Though the total apple crop at East Malling was slightly less in 1950 than in the previous year, this must not be regarded as an indication of the yields in the south-east of the country as a whole. One of the heaviest cropping plantations on the whole Station was grubbed in the autumn of 1949 and others thinned, and the new plantings established since the war are not yet in full production.

A total of 12,573 bushels (40 lb. to a bushel) was marketed, only 1,276 bushels less than in 1949, a very satisfactory total, particularly as most of it was high quality dessert fruit. It is worth noting that during the last twelve seasons, there have been only three (1941, 1944, 1946) in which the crop of apples has been less than 10,000 bushels and this on a maximum area of fifty acres, where the proportion of mature trees has been gradually diminishing. The size of fruit generally and of apples in particular was a great improvement on last year, and all varieties of apples were remarkably well coloured and free from blemish.

A few years ago it would have been said that Bramley's Seedling, at East Malling, was a variety subject to violent biennial fluctuations in crop. In 1950 we harvested the fourth successive crop of 300 or more bushels to the acre of this variety. This good record may well reflect both better cultural conditions and the higher rate of manuring given to our Bramley's Seedling plantations in recent years. The area under this variety is now reduced to under 5 acres, so that the total crop was reduced to 1,422 bushels as compared with 4,052 bushels from about 9 acres in 1949. However, yields of up to 17 bushels per tree were picked from the rootstock trial on Great East Field. Worcester Pearmain also did well for the sixth successive year, in spite of a rather scanty show of blossom in the spring. A total of 3,594 bushels of this variety was marketed ; although the actual number of fruits was less than in 1949, when the weight (2,576 bushels) was reduced by drought, the size was much better and almost all were marketable.

The outstanding feature of the 1950 apple crop at East Malling was the excellent crop of Cox's Orange Pippin ; 2,445 bushels of this variety were marketed, the heaviest crop since the record year of 1947. All the older plantations yielded well and the younger trees in the post-war plantations made a very useful contribution to the total. Our third principal variety, Lane's Prince Albert, did not crop very heavily. Blossom was rather sparse and the set moderate ; only 875 bushels were gathered as compared with 1,121 bushels in 1949 and 1,359 bushels in the previous year. Some of the dessert apple varieties planted in 1945 are now beginning to produce useful crops, which should before long begin to compensate in value, if not in bulk, for the older culinary varieties now being grubbed.

Pears.—As mentioned earlier, 1950 was an " off " year for pears in most districts and the Research Station was no exception. Weather conditions were unfavourable at blossom time and even Conference, the most regular cropper of all pears, cropped poorly and produced many mis-shapen fruits. This last may be due to grubbing of adjacent trees of other varieties whose replacements are not yet in bearing and demonstrates once again that even Conference does better with provision for pollination than when planted, as it so often is, in blocks by itself. The Dr. Jules Guyot which averaged just over 3 bushels per tree in 1949 bore scarcely any fruit in 1950. The Station's total pear crop was just under 200 bushels (48 lb. to a bushel) of fruit marketed, but there are now only about 1½ acres of mature pears on the Station.

Cherries.—Though there were no damaging spring frosts in this area our cherry crop was very badly affected by high winds and cold showery weather at blossom time. Conditions were worse than they have been for very many years and during the whole five weeks in which cherry blossom was out there were only three days which were at all favourable for bees. Pollination was, in consequence, poor and the set of fruit rather disappointing. Altogether 1,936 halves (24 lb. to a half sieve) of cherries of all varieties were sold. Of the three varieties in the rootstock trial in Church Fields, Early Rivers once more did best, yielding 487 halves, Bigarreau de Schrecken came next with 302 halves and Turkey Heart last with only 248 halves from approximately 90 trees of each of the three varieties. The quality of the cherry crop was not so good as in 1949, for the showery weather at picking time caused many of the Bigarreau de Schrecken to split and so interfered with picking operations that some of the Turkey Hearts could not be gathered until they were rather over ripe. Some, in fact, fell before they could be harvested and this was partly responsible for the relatively small quantity of fruit of this variety that was marketed. The later Morellos, however, which did not split, grew to an enormous size and were a wonderful sample.

Plums.—We now have only a small acreage of plums in cropping, 2 acres of Victoria, 3 acres of mixed dessert varieties, and Czar and Cherry Plum windbreaks. As with cherries our plum crop was considerably reduced as a result of poor pollination caused by the inclement weather at blossom time. The total crop was only 1,239 halves (28 lb. to a half sieve) as compared with 3,032 halves in 1949 and 2,138 halves in 1948. The quality of the Victorias (397 halves) was excellent and most of the crop of this variety was graded and marketed in 12 lb. chips and made a very good price which partly offset the small yield. Our Ontario plums also bore a small crop (65 halves) of good quality fruit which sold well as did Cambridge Gage and Denniston's Superb. Most of the other varieties in our gage collection and rootstock trials on Deadman Field, however, bore little fruit and much of what there was split very badly as a result of the wet weather during the summer The problem of marketing gages so that they reach the consumer at anything like their best is indeed a difficult one. It would seem that the only solution is to grow a fair acreage of two or three sorts that will pollinate each other and to pick them over almost daily. Whether this is an economic proposition under present conditions is doubtful. The remainder of the crop was mostly Czar and Myrobalan from the windbreaks and Warwickshire Drooper.

Small fruits.

As mentioned earlier in this report, 1950 was a good year for soft fruit at East Malling. The heavy fall of snow on the 25th April flattened many black currant bushes to the ground and broke off some of the new fruit-bearing side shoots on the raspberries, particularly early varieties, and it looked at first sight as though much damage had been done. The plants, however, recovered remarkably well and the crops of both currants and raspberries were very satisfactory. The 4 acres of black currants in variety and manurial trials on Merryweather yielded just over 6 tons. Whilst this may not seem a good crop to many specialist growers, it must be pointed out that the variety trial includes several sorts not now planted commercially, and that the manurial trial includes plots where the level of nutrition is deliberately kept low, so that high total yields cannot be expected. The better sorts in the variety trial, which gets reasonably good manuring, really did quite well. Wellington Triple X in this trial, for example, averaged 3 tons per acre.

Loganberries also cropped better than they have done and the yield was a little over 2 tons from just over 1 acre of mature plants. Here again the crop was influenced by the experiments which include manurial, cover crop and training treatments. Among these are some treatments which are now known to have a depressing effect on crop yield. Much useful information has been obtained from these trials and it is now proposed to plant a further loganberry trial, planned in the light of the knowledge gained, to test the cropping capacity of the thornless and thorny varieties and to see if a less expensive method of training can be found which facilitates the control of cane spot and does not entail a reduction in yield.

The total raspberry crop in 1950 was 6¼ tons, rather more than in 1949, although about ½ acre of fruiting trials was grubbed the previous autumn. Some plots showed very serious scorching of the leaves in the early summer and many of the fruiting side shoots were broken off by the weight of snow which fell on them in late April. However, the showery weather in June and July enabled the remaining fruits to mature and swell out well, so that the total weight of fruit picked was much greater than was at first expected.

The strawberry crop was much better than last year, 1 ton 13 cwt. from the 1·2 acres now in small-scale variety and cultural trials. There was little damage to the blossom from spring frosts and a welcome absence of pests and diseases.

Fruit marketing.

During the season a special effort was made to improve the market standards of our fruit. Since the war, like many growers, shortages of labour and packing materials together with price controls had prevented any serious attempt at grading and packing.

To effect an improvement it was first necessary to exercise a more careful control of picking and, bearing in mind recording needs on experimental fruit, try to cut down the proportion of fruit blemished by careless or too frequent handling. Next the packing shed was reorganized, a packhouse foreman appointed, and a start made to assemble and train a team of fruit packers. Grading started with small fruits and, with the opening of the apple season, the Cutler grader was set up and all apples graded for size and quality to Ministry of Agriculture " recommended standards ".

Apart from chip baskets, used for cherries and dessert plums, returnable boxes had still to be used, but most of the apples were wrapped and properly packed therein and the containers covered with cardboard tops.

Undoubtedly our efforts were helped by generally better fruit quality, through efficient disease control and the absence of meteorological disasters ; nevertheless, that well over 70 per cent of our apple crop reached " Fancy " standard must largely be attributed to more careful handling. We should like to thank Mr. A. C. Painter of the Scientific Liaison Section for much help in organizing the packhouse and training the picking, grading and packing teams. At the end of September, a third cold store to hold 2,200 bushels was nearing completion to replace that adapted two years ago for frost research. It is hoped to use it for part of this season's crop.

These efforts resulted in a standard of fruit that was very favourably commented on in the markets and in this season of greatly reduced prices, especially for poor quality fruit, were undoubtedly worthwhile. Generally speaking prices, especially for soft fruits, ruled lower than last year, but the higher proportion of good quality top fruit largely compensated for this.

Fresh plantings and grubbings.

As indicated in last year's Report, our present planting programme is largely directed to providing for the future needs of the Pathology, Entomology and Plant Protective Chemistry Sections. In the autumn of 1950, 9·2 acres of apples and plums were planted on part of the Bradbourne estate (adjacent to East Malling Church) for the Entomology Section. A further $\frac{1}{4}$ acre of apples and soft fruits for the Plant Protective Chemistry Section and 3 acres with nursery material and young trees of all kinds, chiefly for future work on fruit tree viruses, were also planted in the same area. Some 800 dwarf pyramid pears and apples were planted on Plot 21 for future fungicidal work and, during the winter 1950-51, $1\frac{1}{4}$ acres of one-year-old Cox's Orange Pippin and Worcester Pearmain will be planted in Deadman Field for a uniformity trial for the Statistics Section. Two small short term compatibility trials of possible new plum rootstocks were planted in Newgates Field and, also in the same field, various rootstocks and fruit trees for the Biochemistry Section. A special plot is now required to cater for the needs of members of the Biochemistry Section, who frequently wish to burn up, or otherwise destroy, their plant material and cannot, therefore, share other plots where crop records are wanted. This means another large and expensive plot from which there is never likely to be any return, but the importance of the work amply justifies the expenditure that will be involved.

No large areas were grubbed in 1950; activities in this direction were largely confined to thinning and the removal of windbreaks, etc. The poplar windbreak on the west side of Church Fields and part of the Myrobalan plum windbreak on the south of Newgates Field were removed as these only absorb labour, harbour vermin and their value as a protection to fruit plants is doubtful. Much remains to be learnt about the proper use of windbreaks in fruit plantations to give shelter without encouraging frost damage. Undoubtedly some of those planted on the Station in the early nineteen-thirties were wrongly placed and of unsuitable varieties, and these are now being gradually reduced.

The Morello cherries in Egham Field and the Kentish Red cherries in the same field were also grubbed as they were of no further experimental value and contributed little to the farm revenue.

The Grenadiers in an inarching trial, also in Egham Field, were taken out as were the Lane's Prince Albert in the preliminary trial of the Woolly Aphid resistant rootstocks in Great East Field. Both plots had finished their useful life, and besides, it was felt desirable to reduce the area of culinary apples, as these have been so hard to sell in recent years. Now that the walnuts on Churchfields have come into bearing most of the older trees on Newgates Field were dispensed with ; the same applies to the quince collection in Upper Grub and the rootstocks under the young walnuts in Plot C6, all the useful selections having been established elsewhere. The same is true of the species hedge in Great East Field. The fan-trained apricot collection on the walls in Bradbourne Gardens, planted temporarily between the peaches, had also to be removed since the peaches now require all the space.

Plots thinned include the Cox's Orange Pippin plantation in the western part of Kiln Field where the frameworking of some of the trees with pollinator varieties has enabled us to clear certain odd rows of Worcester Pearmain that had been left for this purpose and seriously impeded cultivation. The Plant Protective Chemistry plot in Great East Field and the old apple double-working trials in this field were also thinned, and a start was made to reduce the number of varieties in the mixed apple and pear plantation on Church Fields by eliminating trees which had been frameworked to new varieties bred at the Station, but now discarded.

Routine spraying programme.

No major changes were made in the routine farm spraying programme for the 1950 season. All pears, peaches, cherries, black currants and raspberries were again sprayed with 5 per cent tar oil before Christmas, the weather was favourable and the job finished in good time. It is a great help to get as much as possible of the tar oil on before the turn of the year as there are often few good spraying days in January. The apples were sprayed with 4 per cent DNOC, during the latter part of February and the first ten days of March. This year a DNOC containing 2·4 per cent of dinitro-ortho-cresol was used in preference to the standard product which contains as a rule only 1·8 per cent of this ovicide, as it was felt that this would help to give a better control of aphid, which had been rather troublesome on some plots in 1949. There has been no considerable reappearance of Apple Blossom Weevil since 0·1 per cent of DDT was included in the winter wash used in 1948, so no DDT was included in 1950, except on two small plots where particularly accurate crop records were required. Plums and gages were also sprayed with 4 per cent of the same DNOC with good results and no damage of any kind was seen.

Although there has been very little damage from caterpillars or capsid bugs for several years now, 0·1 per cent DDT was again included in the green cluster lime-sulphur scab spray as a precaution. In spite of the damp showery weather during the spring and early summer, scab was almost completely controlled by sticking closely to the programme set out in the spray calendar and by introducing an extra fungicidal spray both before blossoming and just after the usual fruitlet spray as far as weather conditions and the stage of blossoming allowed ; thus most apple plantations had six scab sprays. As in previous years, lime-sulphur was used on all varieties of apples and pears before blossoming ; after blossoming, dispersible sulphur was used on Cox's Orange Pippin and mercurated lead arsenate on other varieties. Sawfly was well controlled by including 2 lb. of 50 per cent benzene hexachloride wettable powder with spreader in the first post-blossom scab spray and red spider kept in check by adding one pint of liquid derris, again with spreader, to both the fruitlet stage scab spray and the codling spray in early June. Codling Moth larvae were very troublesome in 1950 and damaged far too many good fruits in spite of very thorough applications of the recommended sprays. Greater attention to general orchard and packhouse hygiene will probably help us to combat this most troublesome pest.

Cherries and plums received the recommended copper sprays for the control of bacteriosis and all plums were sprayed in addition with 2 lb. of derris and spreader at the Cot Split stage against sawfly. Raspberries were sprayed twice with 2 lb. 50 per cent benzene hexachloride wettable powder on the spawn in May against Cane Midge ; and black currants were sprayed with 2 per cent lime-sulphur to deal with Big Bud Mite and twice with DDT against midge. Loganberries were sprayed four times in all, once in the winter with 4 per cent DNOC, pre-blossom with 2 lb. of a 50 per cent cuprous oxide preparation, nicotine and spreader against cane spot and aphid, immediately post-blossom with colloidal copper, derris and spreader against cane spot and raspberry beetle and lastly two weeks later with derris and spreader only also for beetle. Strawberries were dusted regularly to keep mildew in check, and on one occasion, DDT was added to the sulphur to control strawberry weevil. Fruiting beds were sprayed with parathion six weeks before picking and non-fruiting beds and runner beds with schradan to control aphid and minimize the spread of virus. These newer insecticides are more effective than nicotine vapour and much easier to apply.

Arable Crops.

The area under arable crops increased by 4 acres to 135 acres in 1950 ; about 8 acres of extra land were made available by the grubbing of our hops (mentioned in last year's Report), but part of this land and a further small area on Bradbourne estate were used for experiments so that the net gain was only 4 acres. Whereas 1949 was an ideal corn growing year and disastrous for potatoes and other roots, 1950 was exactly the reverse. Potatoes and peas flourished, but corn yields were not nearly so good and the weather at harvest time was very difficult in many districts.

Potatoes.—Twenty-seven and a half acres of potatoes were grown in all, 10 acres of Gladstone, 10 acres of Majestic and 7½ acres of Arran Banner. It had not been intended to grow Gladstone and Arran Banner, but the Irish shipping strike prevented delivery of the balance of the Majestic and Stormont Dawn which had been ordered. However, conditions were favourable and all varieties did well. There was quite a severe outbreak of blight, but a proprietary copper spray was added to the Colorado Beetle spray, carried out by the Ministry of Agriculture, and this kept the disease in check until the tops were later burned off with sulphuric acid. The Gladstones, always rather susceptible to blight, suffered most and some of the tubers were affected, so it was decided to market the crop at once and 125 tons of potatoes were sold from the 10 acres of this variety planted. The Majestics also did well, the 4 acre piece in Deadman Field yielding the exceptional crop of 59½ tons of saleable tubers. The remaining 6 acres were grown on some of the poorer Bradbourne Land, but even here the Majestics as a whole averaged just under 12 tons per acre. Of the whole crop, 97 tons were sold to Ditton Laboratory for storage experiments and the remainder marketed in the usual way. The Arran Banner are not yet sold and are still in clamp at the time of writing, but should turn out as well as the other varieties, though rather an ugly sample.

Peas.—Three acres of Surprise and 12 acres of Lincoln peas were grown for canning. Surprise was grown on some rather variable ground in Upper Grub field and did only moderately to yield 3 tons of shelled peas. The Lincoln peas were grown on better land in Newgates field and did exceptionally well and paid handsomely ; for, in spite of a strong growth of fat hen just before harvest, when it was too late to hoe, 22 tons of shelled peas were secured.

Cereals.—Crops of both wheat and barley were only average, approximately 5 quarters per acre in both cases. As in previous years the variety of barley grown was Plumage Archer (December sown) and the wheat acreage was divided between Holdfast and Squarehead 13/4. The barley, being winter sown, matured early and was combine harvested without loss. The wheat was more trouble, but by carting a load or two at a time whenever opportunity offered, this too was secured in good condition before the weather really broke. There were fortunately only 14 acres of hay to make in 1950 and this was cut early and cocked and made some excellent hay. Two acres of a mixture of oats, beans and vetches were made into silage, together with the spent pea haulm, and 8 acres of roots were grown for the bullocks. Forty-five young Devon steers were fed during the winter 1949-50 and did a good job treading the straw from the 1949 cereal crops into dung.

F.H.V.

Experimental nurseries.

The higher summer rainfall in 1950 was just as welcome in the nursery as in other departments of the Farm. Although the frequent showers made weed control difficult and expensive, both trees and rootstocks benefited ; the trees in particular made excellent growth and at lifting time were some of the best grown at the Research Station for several years. After a slow start, doubtless due to the inclement weather in April, cuttings too grew away well though the percentage rooted was not above average.

Owing to the reduced demand, many non-rooted and poorly rooted second-grade rootstocks of the 1949 crop were bedded back in the spring of 1950. This work was done with a modified Ferguson cultivator which cut the grip and firmed in the plants thus saving much hand labour. Results were very gratifying, the " take " being fully equal to that secured by older methods and all cuttings and bedded stocks will be treated in this way in future.

The number of fruit plants raised for experimental purposes was somewhat larger than usual owing to the extensive planting of plots now going on. The total number of one-year-old trees raised was 8,550. Strawberry runner beds were on a small scale again this year and distribution was confined to those growing special stock nursery beds. Ten thousand black currant bushes were raised, largely for sale ; and smaller quantities of loganberry tips, gooseberry bushes and red currant bushes were also produced for experimental purposes.

The new stoolbed of Woolly Aphid resistant stocks was completed in the early months of 1950 and is now well established, though none of this material has as yet been distributed, pending the results of further tests. The number of rootstocks of standard varieties harvested this year from the established stoolbed in Ditton fields was only 412,820, as compared with 518,500 in 1949, as the acreage has been reduced by grubbing and will be reduced still further as demand slackens, and will eventually be sufficient to meet experimental needs only.

The weather during November and December, 1950, when the lifting of nursery material was in full swing, was appalling, rain, frost and snow succeeding each other in quick succession. However, by the introduction of piece work and by ploughing some of the soil away from the stools it was possible to get all stocks off well before Christmas. Nursery trees, currant bushes and bedded stocks were all lifted with the help of a modified Ransome cultivator. The use of this implement, evolved by the

nursery foreman and workshop staff, reduced lifting labour by quite half as compared with older methods and was of the greatest assistance during this very difficult season (see p. 201).

There was little trouble with pests this year and the routine sprayings kept the nursery clean. Apple Mildew was rather troublesome in the stoolbeds and on bedded stocks, but this was cleared up satisfactorily by two applications of lime-sulphur.

The propagation of Amos Black black currant is continuing and there will be a further distribution of bushes in 1950-51. More graftwood of the new apple variety Tydeman's Late Orange will also be available.

T.V.D.

Part II

GENERAL REVIEW OF RESEARCH WORK
WITH LISTS OF PAPERS PUBLISHED DURING THE YEAR

I. POMOLOGY

By. W. S. ROGERS

Tree fruits.

The long-term experiments covering some 100 acres have all been maintained, and details of those described in recent Annual Reports need not be repeated here.

Rootstocks.

The classical apple rootstock plots, consisting of Lane's Prince Albert, now 33 years old, Worcester Pearmain and Bramley's Seedling, 31 years old, and Cox's Orange Pippin, 28 years old, have all cropped well, and none of the rootstocks has shown signs of senescence. The younger trials are developing well, and many of the lightly pruned trees yielded nearly two bushels of fruit at 5 years old. A paper on rootstock influence on spray damage appears on page 132.

The oldest cherry rootstock trial is now 22 years old. In a younger trial, comparing an acid and a sweet cherry rootstock under the variety Frogmore, there has been little difference in cropping at 7 years old ; the trees on the acid rootstock are smaller but poorly anchored, requiring a permanent stake ; they also sucker freely.

Trees, imported from Australia in 1947, of five sweet cherry varieties worked on Kentish cherry (*P. cerasus*), a dwarfing but normally incompatible stock, are alive and growing. If they remain satisfactory they will be used as sources both of rootstocks and scions.

The plum, pear, peach and apricot rootstock trials have been maintained.

Incompatibility.

Field and histological studies on stock-scion incompatibility have been increased (see below). A trial has been planted of double-worked pears on quince rootstocks to study the growth of compatible and incompatible combinations and to correlate tree performance with the histological structure of one and two year old unions of similar trees.

The degree of inter-compatibility of various plum rootstocks has been examined, and a series of apple, pear and plum varieties are being raised on their own roots for compatibility studies.

Histological investigations.

Observations were made on the amount of starch and the necrosis of the phloem in stems and roots of some compatible and incompatible combinations of peach. The symptoms in certain combinations were compared with the somewhat similar symptoms recorded for the quick decline disease of citrus.

Studies were made of the unions of some compatible and incompatible combinations of double-worked plum and pear trees. The starch content of the sections was noted and some histological characteristics of the wood and of the cambial zone recorded.

A paper entitled " Studies of compatible and incompatible graft combinations with special reference to hardy fruit trees " is in the press.

The distribution and length of fibres and fibre-tracheids in the stems of apple and plum varieties is being recorded in order to determine the relationship between these features and the mechanical strength of the stem.

Further observations have been made on the stem structure of some fruit tree rootstocks and certain other plants in relation to ease of vegetative propagation.

Work on the mycorrhizal association of apple and strawberry has been continued. Permanent sections have been prepared of the different stages of infection and its seasonal progress. Special attention has been given to the early stages of infection.

New plantations.

The comparable plantations on Churchfields (loam) and Larkfield (sand) continue to give interesting contrasts. The trees on Larkfield, though checked by the droughts of 1947 and 1949, produced an excellent crop of highly coloured fruit in 1950. Branch breakage records show more damage on Larkfield than on Churchfields, however.

Propagation.

The terraced island in Bradbourne lake is now in use for experiments with cuttings. In spite of certain difficulties, good results have already been obtained in some treatments with Brompton hardwood cuttings and with the apple rootstock Crab C.

In collaboration with the Nursery Research Station at Boskoop, Holland, a trial with the rootstocks Brompton, Myrobalan B and Crab C was planted in the peat soil at Boskoop, on the Bradbourne island and in the East Malling soil. The joint work is planned to investigate problems of source of cuttings, hormone treatment and winter storage of cuttings. These studies are continuing in close collaboration with the Physiology Section (see page 30).

The Yellow Kroosjespruim, a clonal plum rootstock commonly used for peaches in parts of Holland, has been collected for testing. Rootstock collections have been supplied to institutes in this country and in Australia, Denmark, France, Italy, Norway, Sweden, Switzerland and the United States.

Special methods have been developed for grafting very young apple seedlings to clonal rootstocks and mature trees in the hope of inducing early fruiting of the seedlings (see page 71).

Double working.

The investigations into the effects of double-working upon compatibility, growth and cropping of pears and cherries continue. The possibility of a further simplification of nursery methods is being explored.

Soil management.

The long-term cover crop trials continue to yield useful information.

Small observational plots have shown that several grass species are worth investigation as alternatives to perennial rye grass, and a new large-scale trial is being planned.

The short-term ley experiment, started in 1940, was concluded, in its original form, by a two year period of cultivation. A new trial has been started in the same plantation to investigate more intensively the relative effects of grass and cultivation, in both cases in the presence and absence of added nitrogen, on the uptake of mineral nutrients by the tree. The Biochemistry Section is collaborating in this trial (see page 36) and in the cover crop investigation on the sandy soil at Larkfield.

A preliminary investigation of the use of permanent straw mulch as a system of management for apples is being carried out in a " non-cultivation " trial which also includes three weedkiller treatments (see below and also under Black Currants, page 26).

Inorganic fertilizers.

Observations are being continued in the two long-established inorganic manurial trials.

Weedkillers.

A trial was started in which sodium chlorate, 2-methyl-4-chlorophenoxyacetic acid and a DNOC-fortified oil emulsion are applied twice a year in an apple plantation of four varieties. As in the 1949 trials, the first season showed no adverse effects of application of these weedkillers. A straw mulch treatment is included in the trial for comparison, as well as the usual cultivated control plots.

The A.R.C. Unit of Experimental Agronomy, Oxford, have kindly given advice and materials for the weedkiller trials.

Soil studies.

In the ten years since the start of the main programme of research on cover cropping, several important general conclusions have been reached regarding the effect of cover cropping on fruit trees. Further advances in this subject depend on acquiring a more exact knowledge of the soil conditions produced by soil management practices under orchard conditions. A new appointment now makes possible the planning of a programme of work aimed at obtaining this information.

Special attention is being given to soil physical conditions. The earlier soil moisture studies by means of tensiometers are being continued. Newly developed manometer-type instruments, used in the non-cultivation trial mentioned above, have shown the conservation of moisture by a straw mulch. Further tensiometer data have been obtained in the main cover crop trials, in the Bradbourne island and in a black currant trial where straw mulch was also found to conserve moisture. Soil temperature

records were also obtained in this trial on black currants and in some of the cover crop " museum " plots. Preliminary observations have also been made on volume-weight, porosity, pore size distribution and percolation rates.

Soil sampling has been carried out in several experimental plantations and analyses will be undertaken when the new laboratory is complete. The soil samples taken in connection with the investigation on the restoration of soil uniformity (see below) were kindly analysed by the N.A.A.S.

Restoration of soil uniformity.

An important new joint investigation with the Statistics Section (see page 29) is concerned with the restoration of soil uniformity in areas from which old fruit trees have been grubbed. In an area of four acres from which thirty-year-old Bramley's Seedling trees were grubbed in 1949, the resulting soil variation is being measured, and several remedial treatments are being tested. These are, deep and shallow ploughing, two levels of manuring, and a three year compared with a seven year agricultural rotation before planting apple rootstocks as a test crop. The initial soil samples were taken just before the trees were grubbed. The first crop to be grown on the area was mangolds which showed clear leaf-colour differences at the end of 1950 corresponding with the old tree positions. Photographs taken from a 70 ft. fire escape, by courtesy of the N.F.S., and from the air, with the aid of the R.A.F., showed these differences clearly. At the time of lifting, leaf samples were taken for analysis by the Biochemistry Section and records made of the weight of mangolds per unit area at various points in relation to the old tree positions.

This experiment will be of value, not only within the Research Station, as more of the plots have to be used over again, but to other horticultural stations, both in this country and elsewhere ; as far as we are aware, no such experiment in restoration of soil uniformity has been undertaken previously.

Pruning.

A growers' bulletin on renewal and spur pruning methods has been published (E323) and a paper on the production of a primary branch framework on plum trees using growth substances appears on page 76.

Studies of pruning methods in relation to biennial bearing are being continued. Regulated trees of Laxton's Superb are already strongly biennial at five years old, and some are out of step with the rest.

The bush peaches in a pruning trial at Bradbourne made strong growth during 1950. On those trees winter pruned at planting, a number of branch leaders failed to grow in the spring. On those pruned in May only a few dead tips a few inches long were removed.

Fruit thinning.

The apple thinning trial, using the leaf count method, begun in 1945, has been maintained.

Biennial bearing.

In new trials attention has been concentrated on attempts to find chemical sprays suitable for large-scale defoliation in the " off " year and for blossom thinning in the " on " year. In a preliminary trial five different chemical defoliants were applied to branches of Laxton's Superb, Miller's Seedling and Bramley's Seedling. Differential responses of the three varieties were recorded.

A full-scale spray defoliation trial has been carried out on Bramley's Seedling. Fair success has been obtained by the use of a copper sulphate spray, but the full effect will not be seen until the 1952 crop is harvested.

A blossom thinning trial has been carried out in collaboration with the Physiology Section (see page 31).

The grafting of shoots from " on " and " off " year trees of Miller's Seedling on to renewal pruned trees of Cox's Orange Pippin was carried out in the spring. These are being observed, to see whether the phase of the biennial scion affects the differentiation of fruit buds of the Cox.

Spur life history studies have been continued, and the variety Laxton's Superb has now been included. The results of this work have led to a study of the spurs of some ten new seedling varieties of apple bred at East Malling, to determine their natural cropping regularity or otherwise at an early stage.

A growers' bulletin was published (E339) giving current recommendations.

Frost-damage investigations.

The frost laboratory has been equipped for sprinkling experiments, and several other improvements have been made.

The promising results of experiments on water sprinkling as an anti-frost measure were published (E332).

In 1950 methods were devised for testing different types and durations of sprinkling both in the field and laboratory ; but no spring frosts severe enough for field tests occurred. Laboratory tests on fineness, timing and duration of spray gave valuable data on possible water economies. It appears that intermittent sprinkling may be an adequate protection. The amount and frequency of application needed, in relation to temperature, is now under test.

A paper on frost damage symptoms of different species and varieties was published (E333). Further work on varietal resistance included 5 apple varieties at five stages of development, and also 9 black currant, 11 raspberry and 11 strawberry varieties. In currants, Seabrook's was consistently less damaged than others. In raspberries, Malling Enterprise was again among the least damaged, and Malling Landmark the most. Some of the newly imported American strawberry varieties were less damaged than English ones. Of the latter, Royal Sovereign was least damaged and Madame Lefebvre the most.

Further tests were made on factors affecting supercooling. All blossoms in laboratory tests are now wetted before freezing, to lessen supercooling effects.

Preliminary tests on hardening in apple blossom were made, both in relation to frost damage and, in collaboration with the Biochemistry Section, to chemical changes in the flowers. Certain changes associated with hardening were found.

The effect of growth substances on recovery after frost damage and on setting of flowers was tested in collaboration with Professor Wain, of Wye College, who kindly supplied some twenty-six substances. Some of these caused initial swelling, some delayed abscission, some both stimulated swelling and delayed abscission. None, as used, was effective in causing frozen blossoms to develop into mature fruit, but the work clearly deserves to be carried further. A progress report appears on page 65.

Intensive fruit culture.

A pruning and rootstock trial of Cox and Worcester cordons has been completed and the trees grubbed. The results are being prepared for publication.

Records have been continued on a leader tipping trial on cordon apples, and on pruning trials of apple and pear dwarf pyramids.

In the trial of fan-trained peaches on four rootstocks the uniform training of the fans is being continued. All made good growth but differences in vigour are becoming marked.

Varieties and classification.

The new apple varieties cropped this year on the Churchfields plantation. From comparable trees, Early Worcester was picked two weeks before Worcester. An excellent first crop of well-coloured Late Orange was harvested. Time of blossoming is being recorded on each variety in this trial.

In the gage and plum variety collection, now thirteen years from the bud, Warwickshire Drooper again bore the heaviest crops, with 130 lb. per tree. Jefferson's Gage, Ontario and Oullin's Golden Gage bore 60 lb., Bryanston Gage 50 lb., and Late Orange and Deniston's Superb 40 lb., per tree.

In the apricot collection at Bradbourne all varieties bore a crop ; those with heavy crops were Bulida, Early Moorpark, Old Cape, Croughton and Moorpark. Once again Moorpark ripened a good week in advance of the so-called Early Moorpark. Most of these trees will be grubbed to make room for the peach variety and rootstock trial.

A nursery trial of five varieties (Croughton, Old Cape, Bulida, Early Moorpark and Moorpark) on seven rootstocks (Brompton, Ackermann, Michaelmas Prune, St. Julien A, Broad-leaved Shiny Mussel, Myrobalan B and *Prunus besseyi*) has been started as a preliminary to a possible future field trial.

Breeding.

Selection work among apple seedlings raised to provide dessert varieties of quality has been continued. Material from crosses between late-flowering apples is being prepared for planting out in fruiting quarters. Similar work is in progress with pears. The breeding and testing of apple seedlings for resistance to Woolly Aphid has been resumed in collaboration with the Entomology Section. Further experiments upon methods of hastening the fruiting of apple seedlings are in progress.

The possible effect of the pollen on the development of the fruit of Cox's Orange Pippin was investigated using King of the Pippins, Ellison's Orange, James Grieve and Worcester Pearmain as pollinators. Observations on the chemical composition of mature fruits differently pollinated were

made by the Biochemistry Section and the collaboration of the Ditton Laboratory in carrying out other tests is gratefully acknowledged. This work is being continued.

Rabbit repellents.

Small-scale experiments were conducted with three repellent materials obtained from America, Diamond " L " deer repellent, Goodrite Z.I.P., and U.S. Wild Life Service Rabbit repellent 96A, using bundles of treated apple shoots placed in a latin square arrangement in a rabbit infested area. The only material that gave a significant degree of protection from bark damage was compound 96A. Experiments designed to show the phytotoxic effect, if any, of this compound are in progress. A further large-scale trial of this compound has been planned in collaboration with the Infestation Control Department of the Ministry of Agriculture.

Small fruits.

The trials of strawberries, raspberries, black currants and loganberries, covering some ten acres, have been continued.

Variety and strain trials.

Strawberries.—Auchincruive Climax and Perle de Prague remained the heaviest croppers. One plot of Perle de Prague, at the ripe old age of six years, still bore a commercial crop, but showed virus breakdown by the end of the season.

The crop from autumn deblossomed Climax plants did not differ significantly from that of plants allowed to bear an autumn crop.

Plants of the variant form of Royal Sovereign with adpressed petiole hairs have shown no other differences in habit, vigour or crop from the normal Royal Sovereign.

Raspberries.—Two more varieties, Malling Jewel and Malling Exploit, were named and described (E335).

Yields were lessened in 1950 by an unexplained leaf scorch, which affected some varieties, particularly Malling Exploit and Malling Z, more than others.

In the four-year-old trial of twelve varieties, Malling T was the leading variety, with 3·3 tons per acre. Norfolk Giant was fifth.

In a small trial, planted in 1947-8, including the New Zealand and Amos stocks of Lloyd George, the New Zealand stock led, followed at some distance by Malling Promise, Exploit and the Amos stock, which were close together.

Black Currants.—Yields in the variety trial this year were good. Triple X came first followed by Cotswold Cross, the latter variety doing better than normal.

Propagation.

Strawberries.—Only plants from the insect-proof gauze house were used as parents in the 1950 runner beds. They were spaced at 9 ft. square to form single-plant blocks. This is rather wasteful of ground, but gives maximum yield and facilitates roguing.

The new M.48 clone of Royal Sovereign was distributed to Special Stock raisers, from isolated nurseries in Kent, in autumn, 1950.

Breeding.

Raspberries.—Several more selections from Families 60-72, germinated in 1945, were planted out for observation together with a few selections of the black raspberry (*Rubus occidentalis*) and of hybrid seedlings germinated in 1948.

The seeds of 12 further families, sown in August and September, 1949, germinated well. Some 1,400 seedlings of these families have been planted out ; 500 or more of them should begin to fruit in 1951.

Black Currants.—Several black currants (including Amos Black) selected for commercially valuable characteristics are under observation. Selection is being carried out among currants collected in North-Eastern Europe for material likely to be of use in breeding. Hybridization between the black currant and other related species has been continued and the use of colchicine as a means of inducing polyploidy in such material is under investigation.

Gooseberries.—Spineless gooseberry varieties from Canada have been successfully established and will be used in an attempt to obtain spineless gooseberries suitable for culture in this country.

Strawberries.—Breeding work with this fruit has been discontinued.

Cultural measures.

Strawberries.—A growers' bulletin (E329) was published, and a paper on spacing trials and matted systems is in the press. Trials of spaced and matted rows with Huxley were continued. In one of these the matted row is derived from parents planted at 3 ft. square, i.e. half the usual number of original plants per acre.

Three trials of weedkillers were made. Two of these, on a one year old runner bed of Auchincruive Climax, were devoted to the growth regulating substances 2-methyl-4-chlorophenoxyacetic acid (MCPA) and 2-4-dichlorophenoxyacetic acid (DCPA). The sodium salts of both these substances and the triethenolamine salt of DCPA were compared, using three concentrations of each, while the second trial tested four different times of application of the sodium salt of DCPA. The third trial, on newly planted Royal Sovereign, was a comparison of isopropylphenyl-carbamate with 2 : 4-dinitro-sec-butyl phenol, the latter being applied both in oil emulsion and as an aqueous solution of the ammonium salt.

Raspberries.—A DNOC-fortified oil emulsion was used as weedkiller in a trial on raspberries, but no control of grasses was obtained. A pilot experiment was carried out to test MCPA and trichlor-acetic acid as weedkillers, and a straw mulch as an alternative non-cultivation system. The latter treatment appeared promising, and a large-scale trial is being planned to test the permanent straw mulch as a system of management for raspberries.

Loganberries.—The manurial and training trial on loganberries was ended with the 1950 crop.

Black Currants.—The three manurial trials were continued, and two further trials were started to compare a permanent straw mulch with cultivation as systems of management.

Besides observations on the growth and cropping of the bushes, records were made of air temperature during the blossom period and of soil moisture and soil temperature, interesting results being obtained.

Frost.

The frost investigations include many small fruits (see page 24). In the field trials of straw mulches particular attention is being paid to frost incidence in the blossom period.

Nuts.

Many of the walnut trees carried very heavy crops this year, although certain varieties showed imperfect ripening of the shells.

Horticultural meteorology.

Routine meteorological observations and special records of air temperature and soil moisture in relation to various experiments have been maintained.

Cup counter anemometers erected in three orchards in Kent have yielded some interesting data.

A Crop Weather Station has been established as a sub-station of East Malling on a fruit farm in Kent on the 500 ft. contour.

The Meteorological Office has again kindly provided frost warnings.

Publications During the Year.

In relation to tree fruits.

Tydeman, H. M. **In search of new fruits.** Fruit Year Book, 1949, 13-19 (E304).

Preston, A. P. **Observations on the pruning of bush apples by renewal and spur methods.** Fruit Year Book, 1949, 45-9. Rep. E. Malling Res. Sta. for 1949 (1950), 151-3 (E323).

Grubb, N. H. **Cherries for the garden. A discussion opened by N. H. Grubb.** Fruit Year Book, 1949, 119-27 (E324).

Garner, R. J. **Grafting.** Research, 1950, **3**, 248-53 (E330).

Rogers, W. S. and Modlibowska, Irena. **Low temperature injury to fruit blossom. III. Water sprinkling as an anti-frost measure.** Rep. E. Malling Res. Sta. for 1949 (1950), 63-8 (E332).

Modlibowska, Irena and Glenn, Elizabeth M. **Notes on frost damage symptoms on fruits in 1949.** Rep. E. Malling Res. Sta. for 1949 (1950), 69-70 (E333).

Garner, R. J. **Studies in framework grafting of mature fruit trees. V. Fifteen years of comparative performance of frameworked and topworked apple trees.** Rep. E. Malling Res. Sta. for 1949 (1950), 71-4 (E334).

DAVIES, MOYA H. E. **Towards the control of biennial bearing.** Rep. E. Malling Res. Sta. for 1949 (1950), 154-5 (E339).

In relation to small fruits.

ROGERS, W. S. **Strawberry varieties. Notes on the coloured frontispiece of the Fruit Year Book,** 1949, 49-50 (E317).
——— **A chimera in the cultivated strawberry.** Nature, Lond., 1950, **165**, 120-1 (E320).
——— **Strawberry cultivation to-day. (Condensed from paper read at N.A.A.S. Soft Fruit Conference at Lincoln.)** Grower, 1949, **32**, 967-9 ; Rep. E. Malling Res. Sta. for 1949 (1950), 163-5 (E329).
GRUBB, N. H. **Two new raspberry varieties.** Rep. E. Malling Res. Sta. for 1949 (1950), 75 (E335).
VILLIERS, F. H. **The Experimental Farm.** Rep. E. Malling Res. Sta. for 1949 (1950), 15-19 (E337).

Meteorology.

PRESTON, A. P. **Weather conditions during 1949.** Rep. E. Malling Res. Sta. for 1949 (1950), 80-1 (E336).

II. STATISTICS AND RECORDS

By T. N. HOBLYN and S. C. PEARCE

The Statistics Section's work may be divided into two parts : (A) the design and analysis by established methods of the data obtained from a wide range of field and laboratory experiments conducted by all Sections, together with services such as maintaining the Record Office, summarizing data, preparing maps, etc., and (B) the research programme, which itself may be divided : (i) studies on methods of experimental design and (ii) biometric studies on the variation of plants, the incidence of insects and diseases that attack them and the soil or climatic factors that affect them ; these include studies of sampling methods. The first verges on mathematics, the second on biology. In 1950 the routine work had so much increased that the research programme was cramped ; while, within that programme, the biometric studies considerably exceeded the methodological in extent. Neither feature would have been unusual a few years ago ; and while, in the field, the emphasis is now on investigations specifically designed to throw light on matters essential for the efficient measurement of experimental results (see page 93) rather than on new methods of plot arrangement, it is likely that the design and interpretation of laboratory experiments may play an increasing part in the Section's activities in the future.

A.—Routine work.

The Record Office now houses some 6,000 files, containing data collected over 36 years. The filing of new data has continued without incident, though lack of space for the future is beginning to cause anxiety.

The preparation of summaries was maintained, with some assistance from other interested Sections.

The surveying of plots and the making of maps had to be curtailed for lack of time. Through the courtesy of the Ministry of Agriculture, a professional surveyor has, however, been preparing a large-scale map of the entire Research Station, so the hiatus need have no serious consequences, while this large-scale map will itself be exceedingly useful in planning new experiments.

Statistical analyses of data increase every year on account of both expansion and complication of the Station's work and the consequent greater complexity of statistical methods. Long-term trials entail so much labour that every effort must be made to glean as much information as possible from the data, even though the unforeseen accidents to which all fruit trees are liable render the recovery of reliable information sometimes very difficult.

Even though the Section may not be responsible for the actual design of an experiment it is frequently called on to advise both at home and outside the Station. The need to look well ahead has been re-emphasized in 1950, when much time has been devoted to the preliminary arrangements for the fruit experiments on the new N.A.A.S. Horticultural Experiment Stations, especially the first of these at Luddington, Warwickshire. While it is anticipated that in due course the Section will be relieved of the responsibility for the actual design and interpretation of the results of these trials, a great deal of planning is necessary *now* so that the material can be ordered and the plantations ready when required.

B.—Research programme.

(i) Methods of experimental design.

In a report (M8) two field trials are described where the nature of the treatments or other special considerations make complete randomization impracticable. A type of design which takes into account these difficulties is described, with the appropriate methods of analysis. No further studies on restricted randomization in experimental design are contemplated at present.

A study has been made of the interpretation of experimental results when only partial information is available about some of the data, e.g. the insects on a certain sample of leaves may be too numerous to count, it being known that there are more than 250 of them, though all other samples can be counted. The investigation did not appear to be leading to a usable method and was concluded.

The purpose and design of calibration trials have been described (M9). Further thought has resulted in more information on how to design such trials when there are three varieties.

The other methodological investigations reported in 1949 are in abeyance.

(ii) Biometrics (plant variation and sampling).

Considerable attention has been given to the ideal size of experimental unit in the cases of four species, *viz.* apple, cacao, strawberry and grape vines. With apples optimum plot size may depend upon the incidence of a crippling disease and the general level of variability, as well as upon the need to economize land and effort. The problem has been considered for both guarded and unguarded plots. A report on the latter has been accepted for publication.

Although cacao is a tropical species, investigation into its variability has proved most useful, for in many respects the results have resembled those obtained for apples. The agreement between two such different species has given confidence in the methods of examination used and the general application of the results. Here also a report has been accepted for publication.

The strawberry investigation has confirmed the suitability of the plot size ordinarily used at East Malling. In certain respects it has led to a modification of the recommendations made in 1938 (Esf34) based upon fewer data.

The plot size to give greatest economy of land does not necessarily economize labour, and both must often be taken into account. This has been illustrated in a study of the results of a uniformity trial of vines (M10).

An investigation has been made into the calibration of strawberry experiments when the treatments are applied within one year after planting. Consideration was given to height and spread at the start of the experiment, blossom weight when the plants have been deblossomed in the first year and fruit weight when they have not. Work has also been done on the correct interpretation of spread measurements of strawberries and the desirability of supplementing them by health records (see page 100).

A sampling method has been devised for estimating mean fruit size with cherries. It was found that accurate records could be made quite simply (see page 93).

(iii) Field trials.

The apple trees required for the new uniformity trial are now ready for planting out in autumn, 1950. Some of these trees will be grown undisturbed for a long period, full growth and cropping records being made, while others will be lifted at intervals for a study of the relationships of various vigour measurements at different ages.

An experiment has been started in collaboration with the Pomology Section (see page 23) to estimate the residual effects on soil heterogeneity of established trees after grubbing and to explore means of restoring the uniformity of the land as rapidly as possible. After soil samples had been taken and different preliminary cultural treatments carried out, the whole four-acre field was sown with mangolds. At the end of the season the positions of the former trees were clearly defined in the growth and crop of mangolds, whatever the treatment before sowing.

Publications During the Year.

Taylor, J. **A valid restriction of randomization for certain field experiments.** J. agric. Sci., **39**, 303-8 (M8).

Pearce, S. C. and Taylor, J. **The purpose and design of calibration trials.** Rep. E. Malling Res. Sta. for 1949 (1950), 83-90 (M9).

Pearce, S. C. **The interpretation of uniformity trials.** Rep. E. Malling Res. Sta. for 1949 (1950), 91-2 (M10).

III. PLANT PHYSIOLOGY*

By M. C. VYVYAN

Vegetative propagation.

The effects of various controlled nutritional conditions on the growth of source plants in sand culture, and on the growth and rooting of hardwood and softwood cuttings taken therefrom have been examined and further trials of cuttings from the same source plants have been made.

Routine experiments with hardwood cuttings have been continued, in collaboration with the Pomology Section ; the terraced island at Bradbourne is now in use. A paper reviewing the use of growth-promoting substances as an aid in propagation has been published (F57) and a further paper has been prepared embodying the results of three years trials. These showed that the " dip " method of applying the growth substance was superior to the " soak " method and that the optimal concentration and the safe range varied with variety and time of taking the cuttings.

Special mention may be made of a trial carried out in collaboration with the Nursery Research Station, Boskoop, Holland. Here hardwood cuttings of Crab C, Myrobalan B and Brompton, each taken in autumn from several sources, were either planted immediately both on Bradbourne island and on Malling loam, or were stored during the winter in soil pits and then planted in spring on the island and at Boskoop. At East Malling the establishment rate for Crab C did not exceed 25 per cent, but values of over 80 per cent were obtained for the plums, a noteworthy result in the case of the valuable Brompton stock. Growth was poor on the Malling loam, fair on the island and by far the best at Boskoop. Source of material, growth substance treatment and storage treatment all appeared to influence not only inherent rooting capacity, but also the ability of the cutting to remain alive, an essential prerequisite of successful establishment. The assessment of these two aspects of cutting behaviour is one of the main aims of present experiments.

Physiology of growth and form in fruit trees.

An intensive experiment on the nature of the mechanism of the reciprocal influence of scion and stock in apple trees has been begun. The four rootstock varieties, Nos. M.II, M.IV, M.IX, and M. XVI, are being combined as scion and stock in all sixteen possible ways, e.g. M.II/II, M.II/IV, M.IV/II, M.IV/IV, etc. Further trees of each variety are being left unworked and there will thus be twenty different kinds of tree in the experiment. For this purpose, some 800 rooted shoots from the stoolbeds of each roostock were planted in the spring of 1950 and the appropriate buds were inserted during the summer. Sample trees were taken at the times of planting and of budding and further samples will be taken at intervals during the next two to three years for determination of the fresh and dry weights of the stems, roots and leaves.

The possible connection between the mechanism responsible for the distribution of growth between stem, root and leaf in a simple unworked tree, and that involved in the reciprocal influence of scion and stock in a composite tree, is being examined. Plans are being made for the growth of trees of each kind in soilless culture so as to eliminate the effect of soil variability and to allow of successive determinations of weight without destroying the trees.

A preliminary experiment on the nature of the mechanism involved in response to stem pruning was commenced this season ; willow cuttings are being used.

A further experiment was carried out this year, in collaboration with the Pomology Section, on the control of crotch angles in the plum by the use of indole-3-butyric acid applied to the cut-back shoot. A report appears on page 76.

Abscission, and the shedding of fruits, blossoms and leaves.

A paper summarizing the results of the use of growth substances to control the shedding of fruits has been published (F58).

The results of the 1949 experiment on the effect of the date of spraying upon the control of June drop in Cox's Orange Pippin have been analysed. They show that if applied early in May, the spray resulted in a temporary reduction in drop, followed by a heavy fall and a reduced final yield. If

* Members of the Staff of the Research Institute of Plant Physiology, Imperial College of Science and Technology, are working in collaboration with this Section.

applied on 1st June, a considerable increase in yield resulted ; sprays applied in mid-June and mid-July had little effect (see also page 111). Bramley's Seedling showed little response to early sprays.

Further experiments on the effects of a delay in picking, and of pre-harvest sprays, upon the severity of fruit drop, and upon the quality of fruits after cold storage, were carried out in 1949 and 1950, in collaboration with Ditton Laboratory. Bramley's Seedling showed little response to the spray in either season and Cox's Orange Pippin showed less drop and less response to the spray than in 1948, in spite of a greater delay in picking. This provides further evidence of seasonal variation in the intensity of drop and in the degree of control attainable by sprays.

The indications, obtained in 1949, that potassium sulphate sprays may reduce fruit drop in Cox, were examined in a larger trial in 1950. Sprays of this substance and of NAA, alone or combined, were applied at three periods in the season ; *early*—before the end of May, *mid-season*—end of June to mid-July, and *late*—August. At each period, sprays were applied on three dates, about ten days apart. Some trees were sprayed on all nine occasions. Unlike experience in 1949, potassium sulphate, applied alone, had no effect on drop. Early sprays of NAA, applied with potassium or alone, resulted in a heavy drop in June. Mid-season sprays of NAA resulted in a heavy drop in August only when applied with potassium. The effect on extension growth was likewise different in the two seasons. In 1949, NAA sprays reduced this growth and potassium sprays had no effect ; in 1950 NAA had less effect and trees sprayed with potassium showed increased growth.

Sprays of NAA at 10 p.p.m., and of α-(2, 4, 5-trichlorophenoxy)-propionic acid (TCPPA) at 5 p.p.m., applied to the apple variety Sunset three weeks before picking, were followed within two hours by fairly heavy rain. Some of the sprayed and unsprayed trees were given a second spray. The results showed that TCPPA at this concentration had no effect this season in spite of the promising indications found in small-scale trials in 1948. The second NAA spray reduced drop from 28 to 8 per cent. The first NAA spray had no effect ; this indicates that rain within two hours of spraying eliminates the effectiveness of this spray (see also page 108).

The possibility of using NAA to control the fruit and leaf-fall often induced by parathion sprays, which was examined with some success in a small trial last year, has been tested in a larger trial in collaboration with Entomology. This year, however, parathion had no ill effects. Similar absence of spray-induced abscission was found in another experiment this year, where trees were sprayed with azobenzene, with azoxybenzene or with the high concentrations of 0·16 or 0·32 per cent parathion (see also page 111).

A paper summarizing the results of intensive experiments on abscission has been published and a further experiment was carried out in 1950 to determine whether there is a critical period in the abscission process in the apple fruit or leaf stalk before which NAA must be applied to be effective. For this purpose pedicels and petioles, from which the fruit or leaf blade had been removed, were either left untreated for a period of from twelve hours to nine days, or were brought into contact with a source of NAA for these periods and the source then removed. The pedicels and petioles abscissed in about nine or twelve days, respectively, if untreated, or if the NAA treatment was delayed for five days in the case of the one or four in that of the other. Apparently by that time some irreversible change had occurred and abscission could not be inhibited. With pedicels, three days in contact with NAA was as effective as contact for an indefinite period, with petioles two days was as effective. The implications of these results have not yet been fully worked out.

The main result of work on abscission in excised plant parts and sections of the abscission zone this year has been to show that sulphanilamide can be used to suppress the growth of contaminants which caused so much trouble in the past. In intensive abscission studies it is desirable to have some simple test object, easy to grow under controlled conditions and available throughout the season. The possibility of using species of *Lemna* is being examined but little progress has been made as yet. A surprisingly marked effect of NAA on the growth of cultures has been found, with an optimum at about 5 p.p.m.

Blossom thinning by sprays.

Experiments on blossom thinning by sprays, begun last season in collaboration with the Pomology Section, were continued with a trial on a larger scale on Miller's Seedling. Blossoms were treated at six stages, ranging from two days before full bloom until four weeks after. Several substances were tried, including oil-wax emulsions, DNOC and the three growth substances NAA (at 40 p.p.m.), 2,4-D (at 5 p.p.m.), and TCPPA (at 5 p.p.m.). The effect on blossom-bud formation will not be known till next spring. The main effect of some of the growth substances was to keep a number of fruits on the tree in an arrested stage of growth. At picking time these were only an inch or less in diameter, though their flesh had matured and their skin had coloured normally. None of these small fruits had any developed seeds.

As a corollary to the work on blossom thinning, a brief examination was made of the effect of NAA on the germination and growth of pollen in culture. Far from inhibiting either, it improved the growth of the tubes ; the concentrations of NAA, however, were lower than those used in the field. Further work is desirable, especially on the growth of pollen tubes in styles treated with NAA, as the action may be on the stylar tissue rather than on the pollen itself.

Hormone relations in fruit trees.

Work on auxin relations in apple and plum shoots has been continued, and extended to those from different cultural sources. The varieties and sources were the same as in the propagation experiments referred to earlier, i.e. Crab C and Myrobalan B and Brompton from a hedge, layers and budded stocks. Ether extraction was used, experiments in 1949 having shown that this extracted auxin from dormant winter shoots. This, not being in a free-moving state, cannot be detected by the diffusion method, and is therefore termed " storage auxin ". Observations on dormant 1949 shoots were started in December and were continued on ten occasions until the summer of 1950. A similar survey of 1950 shoots was started at bud-break and is still in progress. A parallel series of determinations of transportable auxin was made during the growing season by the diffusion method. Disappearance of storage auxin from the 1949 shoots coincided with the renewal of growth in spring and none has been found to date (September) in the 1950 shoots. Auxin differences have been found between shoots from different cultural sources ; these are being examined.

Observations have also been made on the inhibiting factor, recorded last year. The technique has been to measure it as an interference with the normal curvature response to a standard concentration of synthetic " auxin " (indole-3-acetic acid), applied in agar blocks to the coleoptiles. The inhibiting influence was confirmed to be strong in apple shoots, but normally absent from plum shoots. It was present, however, in the roots of both.

Work on the rate of transport of auxin in isolated lengths of stem has been continued and extended. By allowing auxin to diffuse out from the lengths of stem into agar for a known period, and then dividing the stem into short sections and assaying the residual auxin in each, it has been possible to estimate the total auxin content. The rate of transport was estimated by determining the number of sections completely evacuated during the initial period. Experiments carried out at constant temperatures, ranging from 2° C. to 45° C., indicate that total yield of auxin does not seem to be influenced by temperature save that there appears to be a destruction of auxin at high temperatures. The major influence of temperature is on the rate of transport, which rises to a maximum of about 0·84 cm./hr. at 25° C. and thereafter falls.

Preliminary experiments on rate of transport in different rootstocks have been begun.

Fruit-splitting in cherries and plums.

Further work has been carried out on the control of fruit-splitting in cherries and plums, both by the use of sprays of calcium hydroxide, as last year, and by oil-wax emulsions, but the results have been disappointing. Indications were obtained that both these methods may be effective, but neither gave sufficiently conclusive results to warrant recommendations at this stage.

Spray damage.

The normal spray schedules led to little spray damage in 1950 ; the only phytotoxic effect noticed was a slight bronzing of the primary leaves of many apple varieties after the earlier applications of lime-sulphur.

Attempts, in collaboration with the Plant Protective Chemistry Section to induce leaf damage by the use of parathion, azobenzene and azoxybenzene failed even when parathion was applied at the high concentrations of 0·16 and 0·32 per cent. The only damage noted was an interveinal bronzing and purpling of the leaves of Cox's Orange Pippin in September after spraying with 0·3 per cent azobenzene in June. Failure to induce leaf and fruit fall has already been reported above.

During the year a spinning disc apparatus has been set up to produce sprays with drops of a constant size. This will allow of the treatment of individual leaves, and the study of their response to controlled amounts of spray, composed of droplets of known dimensions. Calibration of the machine is in progress and preliminary trials have been made using the leaves of potted apple trees sprayed with 100 per cent lime-sulphur and with various concentrations of ammonium thiocyanate.

PUBLICATIONS DURING THE YEAR.

HATCHER, E. S. J. **The use of growth-promoting substances in the vegetative propagation of plants.** Ann. appl. Biol., 1949, **36**, 562-6 (F57).

VYVYAN, M. C. **The use of growth substances to control the shedding of fruit.** Ann. appl. Biol., 1949, **36**, 553-8 (F58).

BARLOW, H. W. B. **Studies in abscission. I. Factors affecting the inhibition of abscission by synthetic growth-substances.** J. exp. Bot., 1950, **1**, 264-81 (F61).

IV. BIOCHEMISTRY

By W. A. ROACH

During 1949-50 the emphasis of the work in the Biochemistry Section has been on the development of analytical methods. The progress made is considered to warrant the shifting of the emphasis in future towards the application of the methods evolved to pomological and physiological problems.

Analytical methods.

Chemical.

The methods in use for routine analysis have been kept under constant review for possible improvements in precision, accuracy, speed or sensitivity. Wet digestion of plant material using hot concentrated sulphuric acid has been shown to give rise to serious difficulties at later stages of analysis, and these are being investigated. Meanwhile, the dry ashing technique, coupled with sodium carbonate fusion of the acid insoluble residue, is still in use for phosphorus, potassium, calcium, magnesium and manganese. Investigations carried out during the year on analytical methods are summarized below ; full details will be published elsewhere in due course.

Phosphorus.—Various reducing agents were tested under a range of conditions, but none gave a better performance than the hydroquinone adopted as standard.

Calcium.—The calcium oxalate method, though good, is rather tedious and time consuming. An adaptation of a method for testing water hardness has proved to be equally accurate and very much more rapid.

Magnesium.—The Titan yellow method, though the best available, lacks precision and is inaccurate for low concentrations of magnesium. Various suggested modifications have been tested but none has proved better than the one based on the work of Pieters, Hanssen and Geurts and described in the Annual Report for 1949.

Iron.—Much detailed work on the determination of this element has led to a better understanding of the factors causing trouble. These have been brought under control with the result that a satisfactory method is now available. Wet ashing with sulphuric acid and hydrogen peroxide has replaced dry ashing, and special attention has been given to the purification of reagents and measures to ensure complete reduction of the iron.

Manganese.—The standard method based on oxidation to permanganate by means of periodate is satisfactory when there is enough manganese available in the sample, i.e. 1 to 5 μg. A need exists for a precise method of much greater sensitivity than the permanganate colour method. The very sensitive reaction with tetramethyl diamino diphenyl methane (" Tetrabase ") offers possibilities. The transient blue colour has been used for quantitative estimations but the precision and accuracy attainable was found to be insufficient and the use of the final green colour formed with this reagent was investigated. While this work was in progress, a method based on the same idea was published by Cornfield and Pollard. This method, though not entirely satisfactory, has been adopted in this laboratory for quantities of manganese less than 1 μg ; for larger amounts the permanganate colour is used.

Boron.—During the year it became plain that the main source of error in estimating boron in plant material is the serious loss of volatile boron compounds during ashing. Accordingly a pressure (bomb) combustion method has been investigated. A micro-autoclave has been designed and we are greatly indebted to Dr. Tomkins, Superintendent, Ditton Laboratory, D.S.I.R., for arranging for this apparatus to be made in his workshops. Replication has been limited by the difficulty experienced in making a gas-tight seal, but preliminary results with this apparatus indicate that plant material may contain more boron than has hitherto been reported.

Zinc.—Although some work has been done during the year on the estimation of this element, there is little progress to report.

Preparation of the sample for analysis.—An investigation on grinding, drying and conditioning the sample ready for weighing has led to the adoption of an improved technique.

Spectrographic methods.

Flame method.—The apparatus, fully described last year, has been improved in the light of experience. Several hundred samples have been burnt on it in its present form without trouble. The design of the apparatus has been proved by experience to be satisfactory but there are grounds for the fear

that trouble may arise in the future from slight imperfection of finish arising from the absence of precision workshop apparatus, in particular a milling machine. The present apparatus was constructed in the laboratory largely from odd parts from an American bomb-sight.

The instrument can now be used for semi-quantitative comparative analysis of samples for the elements : magnesium, copper, sodium, potassium, iron, manganese, lithium and rubidium by burning a 10 or 15 mg. sample of ground material enclosed in the cellophane cartridge. Recent work gives grounds for the hope that the method will prove fully quantitative for manganese, potassium and possibly for sodium, lithium, magnesium, copper and iron and other elements.

The very considerable influence of phosphate on the emission by calcium does not allow of the quantitative estimation of the latter, at least at present.

Arc method.—Less than 1 p.p.m. of cobalt, nickel and molybdenum in a 50 mg. sample gives lines that can be quite easily seen in the absence of magnesium and potassium when samples are examined by the arc method. Similarly less than 10 p.p.m. of zinc in a 100 mg. sample gives lines that can be seen. In the presence of magnesium and potassium the emission of these elements is very considerably suppressed. Since the amount of cobalt normally present in plant material is less than 1 part in 10 million, it is clear that for the determination of these trace elements it is necessary to use at least 2 gm. of material, and that they will have to be separated from the major elements.

Mass Spectrometer method.

As a result of further delays in the physics laboratory of Messrs. Metropolitan-Vickers Ltd., little progress has been made in this work, but it has now been started.

Fractionation of nutrient elements.

Progress has been made in the evolution of a method sufficiently simple to be applied as a routine, and preliminary results suggest that further work is justified.

Organic constituents of fruit plants.

The equipment of the new organic chemical laboratory is now nearing completion and it is hoped that before the end of 1950 work will be in full swing in these more commodious quarters. The lack of laboratory facilities and the consequent severe overcrowding has hitherto imposed a heavy handicap, nevertheless progress has been on the lines indicated in last year's Report. Improvements have been made in the techniques for separating the proximate constituents of plant extracts and their subsequent chromatographic examination and the exploratory investigation of leaves and stems of apple, pear, plum, cherry and quince has been continued.

The results so far obtained indicate that the corresponding amino-acid, hydroxy-acid and carbohydrate fractions of the different fruit plants are qualitatively very similar in composition. This result, if substantiated and further amplified by the quantitative investigation which will be attempted in due course, carries the significant implication that the main metabolic pathways with which these substances are concerned are very similar in all fruit plants. This conclusion is, of course, entirely in harmony with the growing belief, based on biochemical study of animal tissues, yeast, algae, etc., that the essential pattern of carbohydrate metabolism and its linking with nitrogen metabolism is common to all living material. The problem of interpreting the findings of the organic chemist in terms of plant physiology and hence of applying this knowledge to practical ends will be simplified to the same extent as these generalizations are found to be true.

In contrast to the other fractions the " aromatic fractions " (glycosides, etc., extracted by ethyl acetate) are found to differ markedly and each plant will require detailed investigation.

An important object of these investigations is to throw light on the role of mineral nutrients of the plant by studying the relationship between nutritional status and chemical composition. Potato leaves, from plants grown at different levels of manganese in the course of experiments reported below, became available during the year and the opportunity has been taken to compare normal and manganese deficient leaves. Qualitatively important differences in composition of the amino-acid and " aromatic fractions " were observed, but conclusions cannot be drawn until detailed and quantitative investigation has been carried out.

In collaboration with the Plant Physiology Section attempts are being made to separate and identify the plant hormones, and possibly also inhibitors, present in apple shoots. The detection of

indolyl acetic acid in the presence of the other constituents of apple shoots is difficult, but a chromatographic method which has been developed and is at present being tested appears to have solved this problem. The investigation is being continued.

Studies in nutrition.

Analytical determinations.

Analyses by the chemical and spectrographic methods described earlier have been carried out with the object of assisting investigations in progress in other Sections.

Biennial bearing.—Leaf samples taken throughout the growing season from " on " year and " off " year Miller's Seedling trees have been analysed for nitrogen content. Both sets of figures show the usual initial increase followed by a steady decrease in nitrogen content. For each pair of samples the " on " year figure was considerably greater than the " off " year figure. A full chemical analysis of these samples is being undertaken.

In addition, the flame spectrographic method was used to compare leaves from " on " and " off " year spurs from trees in biennial bearing. The lines for manganese, calcium, iron and magnesium were stronger in the " on " than in the " off " year shoots in all 20 comparisons and the reverse was true for potassium in 18 out of the 20 comparisons. The difference in manganese content became more pronounced from July onwards.

Cover cropping.—Samples taken from trees during 1949 (one year after planting out) and 1950 are being analysed for nitrogen, phosphorus, potassium, calcium, magnesium, iron and manganese. The results are not yet complete but interesting effects of some of the treatments are already clearly apparent.

Distribution of elements.—The flame spectrographic method was used to compare 10 mg. samples of corresponding parts of vegetative and fruit buds from Cox's Orange Pippin trees. The parts selected were the inner bud apex (called for short the apex) and the green scale leaves immediately surrounding the apex. The concentration of copper, potassium, rubidium and probably strontium was much higher in the apex than in the scales (this was particularly marked for copper), whereas that of iron and calcium seemed to be the same in each. Comparing vegetative bud with fruit bud, there was no difference in respect to copper, iron or calcium in apex or scales. There was more potassium in both the apex and scales in the fruit than in the wood bud, but the reverse was true for rubidium.

Plant injection.

A deficiency of zinc was diagnosed by this method in Bradbourne Gardens on Edward VII. Other apple varieties growing close by were not affected.

Attempts were made to find a safe cure for iron deficiency by spraying, but these were unsuccessful. Applications to the soil of peat soaked in a solution of ferrous sulphate failed to correct lime-induced iron-chlorosis in strawberries ; spreading a layer of sawdust mixed with ferrous sulphate over the soil was also ineffective.

Studies in manganese deficiency.*

In order to obtain low manganese levels in a relatively short time, the potato plant rather than the apple was chosen for the preliminary work on the physiology of manganese deficiency. Methods have now been developed by which severe manganese deficiency can be produced within a month of the formation of sprouts from the tuber.

The effect of manganese on respiration has been studied ; there is some evidence for high manganese content being associated with a high respiration rate but it appears that manganese does not always limit respiration, as high respiration rates have been obtained in leaves of very low manganese content.

Work on the biochemistry of leaves at different manganese levels is being carried on in collaboration with Dr. A. E. Bradfield and studies in nitrogen metabolism are being made. They have not yet reached the stage at which a detailed report would be justified.

Experiments have been made on the lake-bed at Bradbourne on the effect of carbon-dioxide concentration in the soil atmosphere on the uptake of manganese by the potato plant. Although carbon dioxide concentrations ranged from 5 per cent to 80 per cent and pH of soil from pH8 to pH7·4 no effect on the uptake of manganese was found.

* This work is being carried out by members of the Staff of the Research Institute of Plant Physiology, Imperial College of Science and Technology, working in collaboration with the Biochemistry Section.

Eaton, J. K. **The organic constituents of the apple tree—preliminary work.** Rep. E. Malling Res. Sta. for 1949 (1950), 93-9 (K80).

Bradfield, A. E. and Flood, A. E. **The organic constituents of fruit plants. I. An outline of a method of examination of the water and alcohol soluble constituents.** Rep. E. Malling Res. Sta. for 1949 (1950), 100-4 (K81).

Vanstone, F. H. and Philcox, H. J. **A flame method of spectrographic analysis.** Rep. E. Malling Res. Sta. for 1949 (1950), 105-10 (K82).

Mason, A. C. **The estimation of phosphorus, potassium, calcium, magnesium, iron, manganese and nitrogen in plant material.** Rep. E. Malling Res. Sta. for 1949 (1950), 111-15 (K83).

Delap, Anne V. **The application of trace elements to alkaline soils. A preliminary note.** Rep. E. Malling Res. Sta. for 1949 (1950), 116-17 (K84).

——— **An interveinal injection needle.** Rep. E. Malling Res. Sta. for 1949 (1950), 118-19 (K85).

Bradfield, A. E. and Flood, A. E. **Soluble carbohydrates of fruit plants.** Nature, Lond., 1950, **166**, 264 (K86).

V. PLANT PATHOLOGY

By R. V. HARRIS

Bacteriosis of stone fruits.

Work on the Bacterial Canker of cherries was concentrated this year on the major issues dealt with below.

Further experiments have confirmed the importance of the leaf-spot in the annual cycle of the pathogen *Pseudomonas mors-prunorum* as a source of inoculum for the winter canker phase. Techniques for the quantitative estimation of inoculum present on the leaf surface at leaf-fall were studied. Considerably fewer bacteria were encountered on the leaves of a resistant variety than on those of a susceptible one.

During investigations to determine the source of inoculum for the leaf-spot phase some connection was found between leaf-spot and the number of dead fruiting spurs. This supports the conclusions drawn from previous surveys of the distribution of bacterial populations within the tree (C261). Experiments were made to investigate the ability of the pathogen to overwinter in healthy buds. A limited survival was found.

The possible importance of the autumnal leaf scar as an avenue of infection for the winter canker phase was studied, using three varieties of widely differing susceptibility. Artificial inoculations through leaf scars produced canker and dead spur symptoms equal in severity to those occurring naturally on these varieties. There are indications, however, that other factors besides differing inherent resistances to inoculum may also be involved in the relatively lower number of infections occurring on resistant varieties under field conditions.

In addition to the studies of Bacterial Canker a start was made on a bacterium associated with a blossom wilt and leaf-spot of Morello cherries. Work was continued on a bacteriosis of apricot; the responsible pathogen was confirmed as *Pseudomonas mors-prunorum.*

Apple and Pear Scab.

Reference was made in last year's Report (see page 46) to plans for laboratory studies of the variability in morphology and pathogenicity of *Venturia* spp. These developed during the present year. Collection of isolates of both species, *V. inaequalis* and *V. pirina*, was continued to obtain material for a detailed study of nutritional differences between strains and species. A technique was established for the rapid assay of these differences and of reactions to inhibitors from the hosts. The results so far indicate marked interspecific nutritional differences and wide variation between isolates in their responses to inhibitors (see also p. 45).

Verticillium Wilt.

A paper describing recent extensive laboratory studies of three pathogenic types of Verticillium, made in conjunction with the Botany School, Cambridge, was published (C256).

The work on Verticillium Wilt of the hop continued on two main lines, firstly, the selection of wilt-resistant varieties, and, secondly, a study of the factors influencing the invasion of the plant and subsequent symptom expression.

Primary resistance trials were made of 45 new hop seedlings bred from resistant parents. Many showed high resistance. Propagation of the more promising varieties continued and four quarter-acre plantings of varieties selected in 1949 were made on farms for commercial testing. Second-year records were made on 15 farms of the 1948-49 commercial plantings of the older established varieties OR55 and OJ47. These continued to show promise. About 100 acres of the variety OR55 were planted commercially in 1950 and reports received from growers indicate that further plantings are likely. One garden of mixed 2-3 year old plants of OR55 on fairly heavy ground about $1\frac{1}{4}$ acres in extent gave the high yield of 31 cwt. A number of new selections of wilt-resistant male varieties were made, partly in collaboration with the Hop Research Institute at Wye College, and these are being propagated for commercial planting.

A new project on the breeding of wilt-resistant varieties was started in collaboration with this Institute. Crosses of wilt-resistant male plants were made with the commercial varieties Fuggle 1147

(a resistant English variety grown on a commercial farm) and OT48 (a seedling of Bramling). The pollinations were successful and seeds have been collected for sowing in 1951 at Wye. The object of the experiments is to try to produce resistant varieties which closely resemble, in growing and brewing qualities, the commercial hops at present generally grown.

An experiment designed to test the effects of differential manuring of wilt-infected hops with nitrogen, potassium, and calcium was concluded. As in previous years, the main effect noted was that of added nitrogen, which gave a greater wilt incidence than occurred on the non-manured plots.

Tests have been made of the reaction to soil infection of composite hop plants made by grafting wilt-resistant varieties as scions on susceptible varieties as rootstocks, and vice-versa. The results, if taken in conjunction with those from previous experiments, suggest that the reaction of the rootstock is a prime factor in determining the severity of symptoms on the stem.

Some further studies have been made on the strains of *V. albo-atrum* obtained from progressive and fluctuating hop-wilt outbreaks, but these, as yet, have not given any certain method of laboratory identification of the strain involved.

Preliminary experiments have also been started on the isolation of toxins from Verticillium cultures. This work has been confined to the development of techniques and the standardization of methods for the assay of the toxins. Host plants of Verticillium, other than the hop, have been used in several greenhouse experiments. These include further studies of the effect of host plant nutrition on wilting and a preliminary study of the possible therapeutic effects of various chemicals when absorbed by the plant.

Virus diseases of tree fruits.

Experiments have shown that there are at least two strains of Apple Mosaic differing greatly in the severity of symptoms. An experiment was started to ascertain the effect of these strains on the Malling rootstocks and on four commercial varieties.

A report of the early experiments on the graft transmission of Rubbery Wood was published (C262). Experiments are in progress to propagate a proven non-rubbery clone of Lord Lambourne, to isolate rootstocks of proven freedom from the disease, and to ascertain whether other scion varieties when infected with the virus show detectable symptoms.

Experiments on the Stony-pit and Vein-banding viruses of the pear were started during the year.

Three hundred indicator plants have been bud-inoculated in investigations of various plum viruses and to test rootstocks for the absence of virus. The indexing of symptom types by grafting to indicator varieties yielded the first results this year.

Twenty-seven cherry trees showing different suspected virus symptoms were tested in 1949, using the clonal rootstock 12/1 as the only indicator available in quantity. All but two of these trees proved in 1950 to be infected, and on differential symptoms the viruses can be tentatively assigned to six groups, Tatter-leaf, Rosette, Vein-clearing, Mottle, Rusty Mottle and Rasp-leaf. In 1950 these viruses were indexed on seedlings of peach, apricot and Mahaleb, and on the varieties Early Rivers, Waterloo, Merton Heart and Merton Bigarreau. In the process of indexing suspected viruses found during the year, and also in testing rootstocks and " stock-trees " for virus, over 570 inoculations were made to *Prunus* species and varieties. About 50 cherry orchards were inspected and none was found entirely free from symptoms probably of virus origin.

Virus diseases of soft fruits.

In the course of experiments on strawberry viruses in the three groups described by Prentice, some interesting facts on *Virus* 1 emerged, which are briefly as follows. Both the mild and severe low-persistence viruses can multiply in the same plant and there is some evidence that the mild virus has a longer persistence than the severe. A third non-persistent virus of intermediate virulence has been separated. The relationship of these three viruses to Prentice's 1A and 1B has yet to be determined.

The report of the A.R.C Scottish Raspberry Investigation will be found on page 50.

Two new virus diseases of black currant are being studied. One causes an olive-green mottling as the leaves age; the other, yellow vein-banding and ring-spot. Experiments are in progress on the host range (within the *Ribes* group) and the vectors.

In studies of the virus diseases of the gooseberry, the " giant gooseberry " condition has not been transmitted in grafting experiments, but a vein-clearing and banding symptom, which is very commonly seen, has been transmitted thus to the " giant gooseberries " from the Leveller plants to which they were grafted. Observations suggest that this vein-clearing virus causes stunting in commercial plantings.

Virus diseases of the Hop.

A feature of these diseases is their extreme sensitivity to symptom-masking under high temperatures, and experiments were planned for 1950 on the assumption that temperature-controlled, insect-proof glasshouse accommodation would be available. The fact that this did not eventuate until the end of the season seriously handicapped progress in this work.

The testing of potential insect vectors was continued in an experiment in which 96 large pots were used, each containing four hop plants, one of which was infected with Nettlehead and probably Mosaic, and the three others were healthy indicators. The insects were collected at short intervals from five sites at which virus diseases were known to be spreading. During the year some 36 different insects were thus tested, but results are not yet available.

Additional evidence was obtained of the sensitivity of Nettlehead to high-temperature masking of symptoms. Several varieties were tested for Mosaic expression in the search for indicators more efficient than Bramling.

Analytical experiments by graft transmission were made on the Split-leaf-blotch and Nettlehead-with-enations diseases.

A further trial on varietal resistance to Nettlehead in the field, similar to that at Bodiam, is in progress on a farm in Worcestershire.

Problems of disease control.

Collaboration continued with the Plant Protective Chemistry Section on the testing of new fungicides and is reported elsewhere (see page 45).

A trial of the control of Apple Canker by sprays on five acres of commercial Cox's was started in West Sussex in collaboration with the N.A.A.S. This trial is based on the information provided by pilot experiments, utilizing the method for aiding the natural infection of rootstocks referred to in previous reports.

Full accounts were published (C257, 258, 259) of experimental work on the incidence of Brown Rot on apples and nuts through the medium of certain insect and fungus wound-agents acting as precursors of the disease. Observations were continued during the year both at East Malling and in East Sussex in well-sprayed commercial plantations to determine the extent of Brown Rot losses where the chief avoidable wound agents, Scab and Codling, are commercially controlled.

In the course of the investigations on methods of spray application, the small-scale experiments on the use of atomized lime-sulphur concentrate, applied at low-volume dosage, were continued for a third successive year on cropping Cox's in the plantation, and the results were again highly satisfactory. We now await the development of adequate mechanical equipment for the application of these results to large-scale orchard spraying.

New investigations.

A severe outbreak of Black Rot and Leaf Spot of apple (*Sphaeropsis malorum* Berk) occurred on unpicked fruit in a commercial orchard. Fructifications of *Sphaeropsis* sp. were found extensively distributed on dead wood in this orchard. Isolates from this source induced Black Rot symptoms on inoculation into apple fruits. This relationship is being further studied (see page 137).

The etiology of the Cauliflower Disease of strawberry is being investigated in collaboration with the Entomology Section (see page 43). *Corynebacterium fascians* (Tilford) Dowson was found fairly consistently associated with this condition, and a possible etiological relationship between this pathogen and eelworms was noted.

PUBLICATIONS DURING THE YEAR.

PRENTICE, I. W. and HARRIS, R. V. **Mosaic disease of the raspberry in Great Britain. III. Further experiments in symptom analysis.** J. hort. Sci., 1950, **25**, 122-7 (C246).

ISAAC, I. **A comparative study of pathogenic isolates of Verticillium.** Trans. Brit. mycol. Soc., 1949, **32**, 137-56 (C256).

MOORE, M. H. **This Brown Rot problem.** The Fruitgrower, 1950, **109**, No. 2826, 317-9 ; The Grower, 1950, **33**, 368-71, 417-9 (under different title) ; Gdnrs' Chron., 1950, **127**, 99-100 ; Rep. E. Malling Res. Sta. for 1949 (1950), 169-73 (C257).

——— **Nut rotting of** *Corylus avellana* **L. in relation to the activities of the Nut Weevil,** *Balaninus nucum* **L.** J. hort. Sci., 1950, **25**, 213-24 (C258).

——— **Brown Rot of apples : fungicide trials and studies of the relative importance of different wound-agents.** J. hort. Sci., 1950, **25**, 225-34 (C259).

CADMAN, C. H. **Control of Raspberry Cane Spot in Scotland.** Scottish Agriculture, 1950, **24**, 220-6 (C260).

WEBB, P. C. R. **Bacterial infection of fruiting spurs of sweet cherry.** (*Pseudomonas mors-prunorum* **Wormald and** *Ps. prunicola* **Wormald.**) Rep. E. Malling Res. Sta. for 1949 (1950), 120-1 (C261).

PRENTICE, I. W. **Experiments on Rubbery Wood disease of apple trees. A progress report.** Rep. E. Malling Res. Sta. for 1949 (1950), 122-5 (C262).

POSNETTE, A. F. **Virus diseases of fruit trees.** The Fruitgrower, 1950, **109**, No. 2838, 861-2 (C263).

KEYWORTH, W. G. **Hop propagation in Great Britain.** Wallerstein Laboratories Communications, 1950, **13**, No. 42, 253-65 (C266).

VI. ENTOMOLOGY

By A. M. MASSEE

Tree fruits.

Records of capped blossoms of the Apple Blossom Weevil (*Anthonomus pomorum*) taken on four plots have shown that the infestation still remains light following the almost complete control obtained by routine farm spraying in 1948.

Inoculations have been made in the insectary and orchard house to test the resistance of certain apple rootstocks and seedlings to attacks of the Woolly Aphid (*Eriosoma lanigera*). Of the 450 seedlings tested, 70 per cent proved to be susceptible in their first season, while the remainder are being retained for further testing next year.

A further trial has been carried out to compare the effectiveness, for the control of caterpillars of the Winter Moth and Tortrix groups, of adding DDT to the DNOC spray and DDT and parathion to the green-cluster lime-sulphur spray.

Biological studies of the Apple Sawfly (*Hoplocampa testudinea*) have been continued to determine the times of emergence of adults, oviposition and hatching in relation to the blossom period of the host. A field trial has been carried out to observe the effect of applying parathion, with and without NAA, and nicotine at various dates after petal-fall for sawfly control.

An outbreak of the Pear Sawfly (*Hoplocampa brevis*), a continental pest, was examined, and control measures recommended.

The special investigations on the Fruit Tree Red Spider Mite (*Metatetranychus ulmi*) have been continued at the Field Laboratory, Great Braxted, Essex, and at East Malling. In spite of the rainy weather during July, August and September, there were five generations of the mite, and serious outbreaks occurred in many parts of Essex. Studies of the life cycle of the mite have now been completed, and a detailed report is being prepared. Work has also been carried out on the feeding habits of the mite and on the nature of the leaf injury caused.

The dispersal phase of the Fruit Tree Red Spider Mite has been studied in considerable detail, and it has been ascertained that the adult females disperse in the middle of each of the five generations, when there is a high population of adult mites on the foliage. The suction traps, used for the first time last season, have again proved invaluable in recording the dispersal of mites in the orchard and very useful data have been obtained. The wind tunnel has been modified, and has been used in the laboratory to determine the times at which, and the conditions when, the mites disperse. The information thus obtained has been confirmed in the field.

Summer spraying trials have been continued at two centres in Essex, Runsell Green and Writtle, in orchards which were used last year. At Runsell Green both early and late applications, on 5th and 15th June respectively, of parathion and diphenyl sulphone considerably reduced the mite populations. This applied particularly to each of the early applications. The new derris formulation proved superior to that used last season, but its effectiveness did not equal the parathion sprays. At Writtle 0·01 per cent. parathion gave a commercial control of the mite. Nevertheless, it was noted that the mite populations had built up again by the autumn on the trees where this phosphorus insecticide had been applied. A phytotoxicity trial was also carried out at Writtle in co-operation with the Plant Protective Chemistry Section to test the effect of certain new acaricides upon the variety Cox's Orange Pippin. A comprehensive review of literature on the Fruit Tree Red Spider Mite and its predators, completed last year in collaboration with the Commonwealth Institute of Entomology, was published in February, 1951.

The programme of work on insects and allied animals predatory on the mite has been modified to include a study of the effects of various spray treatments upon the beneficial insect populations of orchards. The new method of estimating insect populations in the field which was introduced last year has been modified, and it is now possible to assess their fluctuations more accurately. Experiments are also being made to study the effects of DDT, BHC, and the phosphorus insecticides upon beneficial and pollinating insects associated with fruit.

Investigations on the control of the Nut Weevil (*Balaninus nucum*) are being continued in collaboration with the Pathology Section. A 5 per cent DDT dust, applied twice during the season, doubled the crop on treated plots compared with untreated ones.

A study of the biology of the apple aphids, with special reference to hatching period and range of host plants has been continued. A field trial to compare the effects of DNOC applied early in March

with those of DDT, BHC, and parathion applied with the green-cluster lime-sulphur spray gave no result, owing to the scarcity of the aphids.

Work on the life-cycle of the Codling Moth (*Cydia pomonella*) is being continued in detail. This includes observations on the emergence of moths, the use of various types of bait traps and the over-wintering of larvae in diverse situations, e.g. in orchards, packhouses and apple boxes. Preliminary experiments have been made on the spraying of packhouses and boxes with DDT, and the parasites and diseases which attack the larvae are being studied. Allied species of Tortricids are being studied in the laboratory and field.

Field trials on modified control measures for the Red Bud Borer (*Thomasiniana oculiperda*) are being continued on the same lines as last year.

Small fruits.

Biological studies of the strawberry eelworms (*Aphelenchoides ritzema-bosi* and *A. fragariae*) are continuing. Organic phosphorus compounds are being used in experiments on the control of these species and of the stem eelworm (*Ditylenchus dipsaci*). Biological studies of the latter, including a study of the host plant range, are in hand. In collaboration with the Plant Pathology Section, an investigation of the causes of the symptom type known as Cauliflower Disease has been commenced, and a preliminary experiment has been laid out to explore the possibility of the Meadow Nematode (*Pratylenchus pratensis*) playing a part in the Strawberry Black Root Rot complex.

Good control of the Strawberry Aphid (*Pentatrichopus fragaefolii*) in field trials has again been obtained by applying parathion pre-blossom to fruiting plants and *bis* (*bis*-dimethylamino)-phosphonous anhydride in early July to maiden beds intended either for fruiting or for runners. The persistence of the latter compound, applied to the leaves of potted strawberries at various dates, is being tested.

The rate of development and fecundity of the Strawberry Aphid at different periods of the year is being studied under insectary conditions. The biology of other aphids found on cultivated strawberry is also being examined, together with their potentialities as vectors of virus.

In collaboration with workers at the Imperial College of Science, experiments have continued to assess the value of methyl bromide as a fumigant in the control of the Strawberry Tarsonemid Mite (*Tarsonemus pallidus*).

In a study of the fauna of cultivated strawberry, additional insects have been recorded to those noted previously.

A field trial has been carried out to determine the value of parathion for the control of the Black Currant Leaf Midge (*Dasyneura tetensi*), and the possible effect of this treatment on fruit set.

Biological studies, with special reference to the hatching period and range of host plants of aphids affecting *Ribes* spp., have continued.

Systematic study of Gall Mites and Red Spider Mites.

Several species have been sent to East Malling for determination and those associated with the Fruit Tree Red Spider Mite have been studied.

PUBLICATIONS DURING THE YEAR.

DICKER, G. H. L. **Further experiments on the control of the Apple Blossom Weevil,** *Anthonomus pomorum* **L.** J. hort. Sci., 1949, **25**, 111-21 (D214).

MASSEE, A. M. **The Apple Sawfly and its control.** Fruit Year Book, 1949, 91-3 (D218).

——— and PITCHER, R. S. **Notes on some interesting insects observed in 1949, with Appendix, Slug damage to raspberry canes** (R. S. Pitcher). Rep. E. Malling Res. Sta. for 1949 (1950), 126-31 (D221).

DICKER, G. H. L. **The Strawberry Aphid** *Pentatrichopus fragaefolii* **(Cock.), and its control.** Rep. E. Malling Res. Sta. for 1949 (1950), 132-8 (D222).

——— **The Shallot Aphid,** *Myzus ascalonicus* **Doncaster, a pest of cultivated strawberries.** Rep. E. Malling Res. Sta. for 1949 (1950), 139-40 (D223).

——— **A note on the effect of DDT in Tar Oil against the Apple Capsid,** *Plesiocoris rugicollis* **Fall.** Rep. E. Malling Res. Sta. for 1949 (1950), 141-2 (D224).

BLAIR, CATHERINE A. **Observations on the life history of the Fruit Tree Red Spider Mite** *Metatetranychus ulmi* **(Koch).** Rep. E. Malling Res. Sta. for 1949 (1950), 143-5 (D225).

MASSEE, A. M. *Hoplocampa brevis* **(Klug)** (*Hym., Tenthredinidae*) **recorded from Kent.** Ent. mon. Mag., 1950, **86**, 224 (D226).

VII. PLANT PROTECTIVE CHEMISTRY

By A. H. M. KIRBY

Laboratory investigations.

Wetting agents.

Experience of the use of di-octyl sodium sulphosuccinate (Aerosol OT) as a wetting agent in both laboratory and field trials has shown that thorough wetting of the underside of apple leaves can always be achieved if 0·02 per cent of this wetter is present in the spray or dipping material. A concentration of 0·01 per cent, or less if another wetter is already present, suffices to give very good cover under field conditions ; a higher concentration tends to cause excessive foaming in the spray machinery and also an undesirable degree of run-off and re-wetting of the deposit. The commercial availability of this compound in this country is now such that growers can be recommended to use it (see also page 214).

Mechanism of ovicidal action.

The power to enhance the toxicity of various ovicides towards the winter eggs of the Fruit Tree Red Spider Mite evinced by benzyl alcohol has been amply confirmed. It appears, however, that it would be unwise to use less than 2 per cent of this penetrant if a suitable effect is to be achieved. There was, however, no evidence that the kill of eggs of *Aphis pomi* or *Operophtera brumata* due to parathion was improved by incorporation of 2 per cent benzyl alcohol ; the latter used alone killed about one-third of the Winter Moth eggs.

An examination of a series of compounds for possible value as penetrants, using 0·03 per cent azoxybenzene as the toxicant, was reduced in value by the relatively high kill, 70 per cent, of winter eggs caused by the toxicant, which had been carefully purified by passage through alumina. This illustrates the difficulty of predicting from year to year what the percentage kill by a given concentration of a toxicant will be. Benzyl cresol was found to give by itself 100 per cent kill of these eggs, but concentrations of 2 per cent of 2,4-xylenol, β-phenylethyl alcohol, 3-phenylpropyl alcohol, piperonyl alcohol and β-phenylethylamine all enhanced the kill due to azoxybenzene, while causing no kill by themselves.

The possibility that the use of a basic penetrant with an acidic toxicant or vice-versa might lead to different results from the combination of two acid or two basic materials or the use of a neutral penetrant, was also investigated. However, there was no evidence that acidic or basic character had any directing influence. Quinoline alone at 2 per cent gave a high kill of eggs, but benzylamine alone at 3 per cent was virtually non-toxic, as was also methyl benzoate at 2 per cent.

A report on these studies during 1949-50 appears in Part III of this Report.

Insecticide studies.

An approximate LD_{50} (at 18 hours) for DNOC in locusts, *Locusta migratoria migratorioides*, has been established, using olive oil as the inert solvent. The value of 6·8-7·0 mg. per kilogram body weight appears to be the same for both sexes, but small changes in dosage have a large effect on the degree of mortality. A similar result was found for DNOCHP, where the corresponding figure is in the region of 5 mg./kg. Similar studies with organophosphorus compounds indicate the following tentative values : parathion, > 0·5 mg./kg. ; para-oxon, > 0·1 mg./kg. ; dimethyl homologue of parathion, between 0·1 and 1·0 mg./kg. ; di-isopropyl homologue of parathion *ca.* 2 mg./kg.

Spraying tests in a Mattersfield tower using *Tribolium confusum* as the test insect showed that the order of toxicity of the above four organophosphorus compounds was : para-oxon ≫ dimethyl-parathion > parathion ≫ di-isopropyl-parathion, which accords well with that for locusts recorded above.

Tests of two systemic organophosphorus compounds were made on locusts, using distilled water as solvents for injection. The following LD_{50} values were obtained : schradan (octamethyl pyrophosphoramide), *ca.* 400 mg./kg. ; *bis*-dimethylamino fluorophosphine oxide, *ca.* 3 mg./kg. These compounds show the same relative activities toward aphids indirectly through treated plants.

A report that 2-methylanthraquinone and benzil acted as synergists for DDT against *Culex fatigans* led to a test of these materials against *T. confusum*. Some synergistic action was found, but not enough to be of value.

Fungicide studies.

A new technique, employing rolls of filter paper held by stainless steel rings, has been developed for the culture of *Venturia* spp. Rapid growth and sporulation is obtained and nutritional studies using liquid media are facilitated. Marked differences, particularly in regard to the nitrogen sources they are capable of utilizing, have been found between *V. inaequalis* and *V. pirina*. No marked differences of this type have been found between strains of the same species, although strains differ very much in spore-production *in vitro* (see also page 38).

Laboratory tests with unsaturated hydrocarbon derivatives indicate that total inhibition of germination of *V. inaequalis* spores can be attained at 0·1 per cent with *w*-nitro-styrene, 1,1-dibromo-2,2-di-iodoethylene and tetraiodoethylene, but that considerable germination occurs if either of the latter two compounds is used at 0·01 per cent. An antibiotic from *Centaurea maculosa* gave only 32 per cent inhibition of *V. inaequalis* spores even at 1 per cent, and only 1 of 10 *Streptomyces* culture filtrates showed activity against spores of this organism.

A surprising result was obtained in studies with pentachlorophenol and its lauryl ester. Two samples of the ester, one " technical " and the other purified, were compared with the free phenol against *V. inaequalis* and *V. pirina*. The commercial ester gave LD_{50} values of the same order as those for the free phenol, but the pure ester failed to prevent full germination even at 25 times these concentrations. Clearly the free-phenol content of the commercial ester cannot explain such a difference in activity.

Tests with a new American fungicide, SR406, showed that complete inhibition of spore germination could be obtained with 0·0016 per cent against *V. inaequalis* and 0·0035 per cent against *Botrytis allii*. Another material of American origin, 4-nitroso-1-*p*-sulphamylphenyl-3,5-dimethylpyrazole (36L), gave almost total inhibition of *V. inaequalis* spores at 0·04 per cent.

Field studies.

During the year, in co-operation with the Entomology, Plant Pathology and Plant Physiology Sections, field studies were made of new insecticides and fungicides, and of acaricides and ovicides for use against the Fruit Tree Red Spider Mite ; a number of phytoxicity trials were also carried out.

Insecticide trials.

Apple Sawfly.—Comparison of several insecticides of the chlorinated hydrocarbon type and of parathion was made with a standard nicotine spray applied to Worcester Pearmain trees on M.IX. The absence of ovicidal action by all the sprays used was established. Considerable control was given by nicotine this year under our experimental conditions, and parathion was again very effective. All treatments, including DDT, gave a high degree of control (see also page 213).

Codling Moth.—This year's trial was confined to a comparison of lead arsenate with zinc fluoro-arsenate, as in 1948, on Charles Ross trees. Neither material gave satisfactory control, but the prolonged period of egg-laying which was a feature of the season could be expected to exceed the persistence even of lead arsenate. There was no significant difference between the effect of the two materials in regard to percentage infested fruits. The details of this work are published in Part III of this Report.

Fungicide trials.

A series of standard and promising materials were compared, using *V. inaequalis* as the test-organism. They were applied to Cox's Orange Pippin on M.IX, twice pre-blossom and once post-blossom (petal-fall). As in 1949, zinc dimethyl dithiocarbamate (ziram) gave the cleanest fruit, followed by phenyl mercury chloride, ferric dimethyl dithiocarbamate (ferbam), 1-*p*-chlorphenyl-3,5-dimethyl-4-nitrosopyrazole (J49) and copper cuprosulphite. TP13 (SR406), thiram (TMTDS), zinc ethylene bisdithiocarbamate (Z78), glyoxalidine 341 C and dispersible sulphur were all of lower, though considerable, activity. Lime-sulphur, applied at 1 per cent throughout, gave only 50 per cent control and was a comparative failure for the first time in our experience. All treatments were safe, except copper cuprosulphite which caused considerable leaf-burn and leaf-drop ; slight leaf-damage followed applications of phenyl mercury chloride, ziram, ferbam, and TP13. Records taken in June showed the least scab on leaves receiving copper cuprosulphite, J49, phenyl mercury chloride and TP13.

Glyoxalidine 341C, phenyl mercury chloride and dispersible sulphur were again compared with normal strengths of lime-sulphur on large trees of Cox's Orange Pippin on a variety of rootstocks, two pre-blossom and one post-blossom (petal-fall) sprays being applied. Damage was negligible on all treatments. Dispersible sulphur (73 per cent S), applied at 0·8 per cent pre-blossom and 0·4 per cent post-blossom, held its own with lime-sulphur, applied at 2·5, 2·0 and 1·0 per cent ; the total sulphur applied was slightly higher in the case of the dispersible form. As noted above, glyoxalidine

341C was rather less efficient this year and phenyl mercury chloride, at 0·05 per cent (active ingredient), was the least effective.

TP13, glyoxalidine 341C and copper cuprosulphite were compared with Bordeaux mixture on three varieties of pear. The incidence of Pear Scab was too low to allow of control being assessed. The copper sprays caused considerable damage, but no harm resulted from the use of the other two spray materials in a three-spray schedule, even on Comice.

Fruit Tree Red Spider Mite investigations.

Two homologues of parathion, the O,O-dimethyl and the O,O-di-isopropyl compounds, were tested in the laboratory against the winter eggs of this pest, but their activities were no greater than those of parathion, para-oxon or the di-isopropyl homologue of para-oxon. Two cyano-hydrins, the acetone and ethylene compounds, also proved of low toxicity. The new American winter-wash, DN289, gave a complete kill of winter eggs in the laboratory at 0·5 per cent of the 30 per cent commercial formulation, equivalent to 2 quarts DN289 per 100 gallons. In Essex, DN289 at this strength was compared in field tests with a DNOC wash containing 3 per cent oil ; neither treatment gave an effective control as judged by leaf records taken on 5th June. This discrepancy between laboratory and field results calls for further trials.

To investigate the possibility that eggs laid in different parts of the country might differ in susceptibility to winter ovicides, material collected from Essex, Sussex, Cambridgeshire and the Station was subjected to concentrations of a spindle-oil or of azoxybenzene calculated to give a 50 per cent kill or less. No evidence that the four samples differed significantly among themselves was obtained.

The majority of the summer trials in the laboratory were made on eggs. It was confirmed that diacetone alcohol could be used as a solvent in place of acetone, up to at least 4 per cent, and that the emulsifiers MB 320, Lissapol N and Lubrol MO were all safe for use in formulating materials for test. The 1949 observation that 2 per cent benzyl alcohol reduced rather than increased the effectiveness of various toxicants was confirmed, using parathion, azobenzene, diphenyl sulphone and K6451 as toxicants. The possibility that the well-known syngergist for pyrethrum and rotenone, piperonyl butoxide, might enhance the activity of rotenone toward eggs was shown to be small ; the butoxide alone, at 0·25 per cent, caused a 40 per cent mortality.

The order of activity of four organophosphorus compounds against the summer eggs was shown to be : para-oxon> parathion> di-isopropyl homologue of parathion ≫dimethyl homologue of parathion. This confirms previous tests with the first two compounds, but the last was relatively much less effective than it was against locusts and *T. confusum* as recorded above.

Among new spray materials, the chlorinated hydrocarbons dieldrin and aldrin were shown to cause mortalities of the order of 50 per cent when applied to eggs at concentrations from 0·1 to 0·025 per cent. β-chlorethyl-β-(*p-tert.*-butylphenoxy)-α-methyl ethyl sulphite (Aramite) proved disappointing, but the new fungicide, SR406, may prove to be a valuable ally against the Fruit Tree Red Spider Mite as it gave a 63 per cent kill at normal field strength of 0·1 per cent. *p*-Chlorphenyl chloromethyl sulphone was found to be as good as, but no better than, diphenyl sulphone.

A trial of compounds related to DMC showed that removal of the methyl group, followed by removal of the two chlorine atoms or transference of them to the ortho-position on both phenyl rings, reduced activity toward eggs in all three cases.

In the case of benzyl benzoate, introduction of a chlorine atom in the para-position on either ring produced a compound having some toxicity towards eggs and greater toxicity toward the adult females than that of the parent ester. The introduction of chlorine atoms at *both* ends of the molecule reduced activity against the females and produced no toxicity against eggs ; this effect is similar to that resulting from the chlorination of azobenzene and diphenyl sulphone.

The new acaricide, K6451, is *p*-chlorphenyl *p*-chlorbenzenesulphonate. American work has indicated that it is very active toward the Two Spotted Mite (*Tetranychus bimaculatus* Harvey), and much more so than the two analogues having one chlorine atom at one or other end and than the unchlorinated phenyl benzenesulphonate. These three analogues were synthesized and compared with purified K6451 ; *p*-chlorphenyl benzenesulphonate was found to be at least as active toward summer eggs as K6451, and this appears to be true for the Greenhouse Red Spider Mite (*Eotetranychus telarius* L.) (personal communication from Mr. W. H. Read). A further trial was made to examine the American claim that K6451, applied to the upper surface only, could kill eggs on the under surface of infested leaves. The order of toxicity of the compounds found to be effective was : *p*-chlorphenyl benzenesulphonate> para-oxon> K6451> parathion> azobenzene. DPS, DMC and rotenone were ineffective.

A report on testing in 1949-50 of materials for summer control of this pest appears in Part III of this Report.

Phytotoxicity trials.

Lime-sulphur, 1 per cent, plus 2 per cent lead arsenate, zinc fluoroarsenate or aluminium arsenate, applied to Cox's Orange Pippin on M.XII and Worcester Pearmain on M.IX on 24th May, caused no damage. Fungicide 341C at 1 quart per 100 gallons, plus 0·2 per cent lead arsenate, was also harmless. In a further attempt to clarify the relative safety of these materials, a second application of all four materials was made on 23rd August. After standing in buckets for 24 hours, the mixtures were transferred to a spray-machine and applied as before. No damage resulted from any of these treatments, in contrast to the results obtained in 1949 when only the mixture containing glyoxalidine 341C was harmless.

No damage was caused by single applications of 341C at 3 quarts per 100 gallons or by 341SC at $4\frac{1}{2}$ quarts per 100 gallons. It was also found safe to apply glyoxalidine 341SC at 3 pints per 100 gallons plus 0·01 per cent γ-benzene hexachloride (in the form of a 50 per cent crude BHC wettable powder).

The new insecticides aldrin (Compound 118) and dieldrin (Compound 497) applied at 0·1 per cent to Cox's Orange Pippin on M.IX caused no observable damage.

A commercial sample of copper cuprosulphite was found to cause considerable damage to both apple and pear varieties. This material was found to have a higher copper content than had the material used in 1949. It would appear that copper cuprosulphite is too phytotoxic for use, but the compound used in 1949 might merit further study.

HETP was sprayed late in May on gooseberry, varieties Keepsake and Leveller, at twice, once, and half the usual field-strength (0·05 per cent). No damage was seen on either variety.

Diphenyl sulphone at 0·1 per cent with and without 0·004 per cent rotenone, parathion at 0·01 per cent, TEPP at 0·025 per cent and *N*,*N*-amyl benzyl *cyclo*hexylamine (Santobane A) at 0·1 per cent, all applied twice in June to Worcester Pearmain and Cox's Orange Pippin in Essex, caused no damage, nor was damage seen following one application of Dimite (DMC) or DCPM in mid-June to these varieties.

An experiment was commenced in collaboration with the Plant Physiology Section to examine the possibility of reducing leaf-fall following applications of certain spray materials. However, no leaf-fall resulted this year from parathion applied at green-cluster at 0·02 per cent, either with or without lime-sulphur ; nor by parathion alone at petal-fall in strengths up to 0·32 per cent, or at 0·05 per cent, twice in early June ; nor by azobenzene at 0·3 per cent or azoxybenzene at 0·1 per cent, each applied at the beginning and the end of June. The year 1950 stands out as a very exceptional one from the point of view of spray damage, copper sprays alone causing harm.

Publications During the Year.

Eaton, J. K. **The cause of black blotch disease of the raspberry.** J. hort Sci., 1950, **25**, 128-31 (Q51).

Eaton, J. K. and Davies, R. G. **The insecticidal activity of some synthetic organophosphorus compounds.** Ann. app. Biol., **37**, 92-104 (Q53).

Davies, R. G. and Eaton, J. K. **Field experiments on the control of Apple Sawfly, *Hoplocampa testudinea* (Klug), by some synthetic insecticides.** Rep. E. Malling Res. Sta. for 1949 (1950), 146-50 (Q55).

McKinlay, K. S. **Mode of action of insecticides used for the control of Apple Sawfly, *Hoplocampa testudinea* (Klug).** Nature, Lond., **165**, 326 (Q56).

Shaw, H., Steer, W. and Davies, R. G. **Laboratory studies on the toxicity of hydrocarbon oils and similar substances to the eggs of some common orchard pests. III. Experiments on the eggs of the Green Apple Aphis (*Aphis pomi* Deg.).** J. hort. Sci., 1950, **25**, 190-212 (Q57).

VIII. SCIENTIFIC LIAISON SECTION

By H. B. S. MONTGOMERY

Advisory correspondence during the past year showed a further slight reduction over that of previous years, although no less than 1,615 advisory letters were dealt with by the Section. A small proportion were passed on to the advisory services and it would seem that growers are becoming better acquainted with the usual channel through which such enquiries should pass. The advisory services were also kept informed of replies to those letters that could not be passed to them for reply.

Visitors, apart from special courses and Members' Days, showed a small reduction, with sixty-three parties amounting to 1,650 visitors and 720 individual visitors.

A Local Day was organized on a Saturday afternoon in June to bring our neighbours into touch with the work going on at the Station. The visitors, who numbered 325, were divided into parties of about 20 and taken on a tour of the laboratories and plantations.

The Pomology Course, arranged in collaboration with the British Council, lasted ten days and consisted of lectures by members of the research staff and conducted tours of the experimental plots. It was attended by fifteen graduate research workers in pomology from Finland, Norway, Sweden, Denmark, Belgium, France, Switzerland and Italy.

Four days for members were arranged, covering the following subjects : growth regulating substances, cover crops and biennial bearing, raspberries and strawberries, and Codling Moth and Brown Rot. In addition, a short programme for members was arranged to precede the second Amos Memorial Lecture, but owing to wet weather the programme had to take the form of a series of short talks under cover. The total attendance at these days and at a special day for the Governing Members of the Research Station to discuss new lines of work that are developing amounted to 900. Great care is required in arranging the programmes for Members' Days, for if the subject under discussion is too wide it is easy to draw more members than can conveniently be accommodated. This is especially true of winter or wet weather meetings, as the only suitable places for lectures are the small packing shed and Bradbourne Great Hall, neither of which can seat more than about 200.

Eleven popular articles written by members of the Section were published during the year and help was given to other Sections in preparing similar articles for publication. Further assistance has been given to the Ministry of Agriculture in producing and revising the official fruit bulletins and leaflets. In February a fifteen minute talk on recent research at the Station was given on the B.B.C. Home Service.

Talks on horticultural research as a career, with special reference to work at East Malling, were given to undergraduates at University College, London, and Queen Mary College, London. Lectures were given also to the Aldershot Garden Lovers' Society, the Ipswich Gardeners' Association and the Aylesford Young Farmers' Club. Members of the Section judged fruit at the Marden Show, the East Kent Show, the Maidstone and District Horticultural Society's Autumn Show, the Cobdown Show and the Platt Show. Educational exhibits were staged at eight centres, including the Chelsea Flower Show, where the exhibit dealt with the predators of the Fruit Tree Red Spider Mite.

Collaboration with the Advisory Services continues to be a very important part of the work of the Section. This is achieved by service on the N.A.A.S. Fruit Group, the Experiments Sub-Committee of the South-Eastern Province and the Horticultural Advisory Sub-Committee of the Kent County Agricultural Committee, and by attendance at meetings of the South-Eastern Provincial Conference. Advisory officers were invited to the rehearsals for Members' Days, courses were organized for officers concerned with the certification of hops and rootstocks, and an annual two-day visit to the Station of a third of the N.A.A.S. Horticultural Staff was arranged. The attendances on these occasions totalled 260. In addition regular contributions dealing with research in fruitgrowing were made to the *N.A.A.S. Quarterly Review*.

Help was given to the Marketing Division of the Ministry of Agriculture in collecting a series of fruit specimens for photography, and by service on the Technical Sub-Committee convened to consider standard grades and packs for soft fruit, apples and pears, and plums and cherries.

Frequent requests for assistance in the preparation of exhibits and lectures were met by the loan of complete exhibits, photographs and other illustrations, or films and slides.

Besides providing an information service to the general public and a link with the advisory services the Section also performs special services of direct help to the staff of the Station. New members of staff have been made familiar with the work of the Station as a whole by specially conducted tours and

by the issue of a weekly summary of the work in progress. Information on specific problems has been collected from growers and the advisory services at the request of research workers.

The Section has again organized the series of sixty lectures on fruitgrowing, its related sciences and the work of the Station given during the winter months to the Plantation Assistants.

As far as time permits members of the Section have participated in suitable lines of research, especially peach culture (see pages 23 and 24) and in trials of rabbit repellents (see page 87) and of chemo-therapeutants against silver-leaf of plums.

Continued assistance has been given to the Farm Staff in improving the handling, storage and marketing of the fruit grown on the Station.

Publications During the Year.

Montgomery, H. B. S. **A minimum spray programme and suitable machinery for applying it.** Fruit Year Book, 1949, 94-9 (T17).

——— **Out of season strawberries.** N.A.A.S. Quarterly Review, 1949, No. 6, 67-9 (T20).

Walker, J. H. **Visit to East Malling Research Station.** J. Inst. Corn & Agric. Merchants Ltd., 1949, **2**, 77-81 (T21).

Montgomery, H. B. S. **Biennial bearing.** N.A.A.S. Quarterly Review, 1950, No. 7, 120-2 (T22).

——— **Modernizing the fruit garden.** Gardens and Gardening, 1950, 157-65 (T23).

Anon. **Spray Calendar,** 1949 Edition (T24).

Walker, J. H. **Trained fruit trees.** The Times Survey of Gardening in Britain Supplement, Sept., 1950, 11 (T25).

Painter, A. C. **Fruit marketing to-day.** Rep. E. Malling Res. Sta. for 1949 (1950), 180-2 (T26).

Walker, J. H. **The model gardens at Bradbourne.** Rep. E. Malling Res. Sta. for 1949 (1950), 156-62 (T27).

Montgomery, H. B. S. **Artificial pollination.** N.A.A.S. Quarterly Review, 1950, No. 8, 167-9 (T28).

——— **Bacterial Canker of plum trees.** Growers' Digest, 1950, **2**, 23-6 (T29).

——— **Rabbit damage to fruit trees.** N.A.A.S. Quarterly Review, 1950, No. 9, 24-6 (T30).

A.R.C. SCOTTISH RASPBERRY INVESTIGATION

By R. V. HARRIS and C. H. CADMAN

Pathology.

Virus diseases.

Experiments on the insect vector relations of the more important raspberry viruses have shown that at least six different viruses are transmitted by the aphid *Amphorophora rubi*. Whilst some of these viruses are transmitted after as little as 6-30 minutes' feeding on the infected plant, none appears regularly to persist in the body of the aphid for more than 24 hours. This unexpected finding, coupled with the fact that the " black raspberry " *Rubus occidentalis*, the principal test plant used in this work, develops only one general type of symptom even when infected with different viruses, may prove a serious obstacle to the use of this vector for the analysis of virus complexes.

The fact that the aphid *Doralis* (*Aphis*) *idaei* transmits at least one of the three vein-chlorosis viruses has been confirmed and its activities as a vector appear to be confined to this group of viruses or virus strains (see page 128).

Despite repeated attempts, no insect vector for the leaf-curl virus has been found. There is ample evidence that this virus is not transmitted by either of the raspberry aphids mentioned above. The results of this year's experiments, which included transfers of aphids from wild plants other than *Rubus* species, are not yet available.

A series of experiments were designed to throw light on the factors conditioning the high resistance of the red raspberry, *R. idaeus*, to aphid-borne infection. These have shown that, contrary to what is known of certain sap transmissible viruses, susceptibility of red raspberries to vein-banding virus (transmitted by *A. rubi*, see page 203) does not appear to increase by subjecting plants to periods of 48 hours in complete darkness prior to inoculation. Further, when comparable lots of *R.occidentalis* and *R. idaeus* are inoculated with 20 viruliferous *A. rubi* per plant, all the former regularly become infected, whilst few or none of the latter do so. Hybrids between these two species appear to be almost as susceptible as the *R. occidentalis* parent. It was also found that young seedlings of *R. idaeus* in the 4-5 leaf stage are appreciably more susceptible to infection than even rapidly growing large plants.

Studies on the rate and manner of spread in the field of certain mosaic viruses were continued this year, in conjunction with trap recording to ascertain the migrational activities of *A. rubi* in or near raspberry plantations in relation to virus spread.

A satisfactory range of indicator hosts for the detection and identification of the viruses so far discovered in raspberries has now been obtained and has provided important data both on strain relationships among raspberry viruses, and on the salient problem of " symptomless degeneration " of " tolerant " varieties.

Field experiments at West Park and the Macaulay Institute for Soil Research, Aberdeen, provided information on the effect of virus infection on the vigour and productivity of Lloyd George and other current varieties.

Stock testing work.

Experience from recent grafting experiments and the use of a wider range of indicator plants have necessitated a revision of the methods now used for the indexing of stocks for virus content. Recommendations on revised procedure have been embodied in a memorandum recently submitted to the Agricultural Research Council, the Ministry of Agriculture and Fisheries and the Scottish Department of Agriculture.

Samples from the stocks of Lloyd George, Malling Exploit, Malling Landmark, Malling Promise and St. Walfried, at present being propagated by the Investigation, were re-tested this season, and the results indicate that these stocks are still free from serious virus infection.

An endeavour was made to select a stock of Malling Jewel of low virus content, as this variety is now in considerable demand. Samples of the six newly selected seedlings included in the Kirriemuir variety trial (see below) were indexed and reserved for use as nuclear stocks.

Fungus and other diseases.

A small trial was made this year to test the efficacy of atomized lime-sulphur concentrate for the control of Cane Spot, and early observations indicate favourable comparison with water diluted sprays. An account of recent trials of the latter was published (C260).

Horticulture.

Nuclear stock propagation schemes.

Virus tested stocks of Lloyd George, Malling Exploit, Malling Landmark, Malling Promise and St. Walfried, and carefully rogued stocks of Norfolk Giant, Malling Enterprise and Malling Jewel are being propagated for the Investigation by a number of growers in Scotland on a contract basis. These arrangements have not proved entirely satisfactory owing, largely, to the unavoidable shortage of labour at the various centres to deal with the detailed work of maintaining these stocks.

A second distribution of the D.1 (New Zealand) Lloyd George stock was made to various centres in the United Kingdom last winter from a harvest of 35,000 canes. A further acre of this stock was planted at Strathallan Castle in the spring.

Several thousand canes of selected stock of Malling Enterprise and Malling Jewel were available for distribution this year from the nurseries planted in 1949. The available virus tested stocks of Malling Exploit and Malling Promise were reserved for the establishment of new propagating centres by the investigation.

Small quantities of the above and other new varieties were supplied to various research and educational units, both in the United Kingdom and overseas.

Experiments with Malling Promise showed that, in the case of this variety at least, softwood cuttings, taken from young suckers, 3 to 6 inches high, root fairly readily under cold frame conditions. By contrast, only 2 of 175 cuttings from young canes, 9 inches to 2 feet tall, formed roots. With neither batch of material was rooting improved by treatment with α-naphthalene acetic acid.

Field trials of raspberry varieties.

Yields.—Despite widespread damage to the crop in late April by severe air frosts, yields this season in many districts were exceptionally high. The two-acre trial of current commercial varieties planted at Slatefield, Forfar, in 1947, yielded some $7\frac{3}{4}$ tons. The Kirriemuir trial of new stocks and varieties planted in 1949 gave 9 cwts. from the total area of one-third acre.

The spring frosts were a severe test of the capacity of the varieties on trial to resist, escape, or recover from, damage. This is reflected, to some extent, in their order of cropping this season. Malling Landmark again topped the list at Slatefield with a yield of 5 tons per acre. Malling Seedling M, Lloyd George (Amos strain), Norfolk Giant and Malling Jewel all cropped in the range 4 to $4\frac{1}{2}$ tons per acre, whilst Malling Promise this year came ninth on the list with $3\frac{1}{2}$ tons.

At Kirriemuir, New Zealand Lloyd George, with a yield of $2\frac{1}{2}$ tons, showed that it can equal the performance of Malling Promise, 2 tons per acre, in giving a substantial return in its first cropping year. Malling Exploit, both here and at Slatefield, was poor compared with its performance in 1949, largely on account of frost damage.

Varietal qualities.—Malling Jewel gave an outstanding performance and attracted many favourable comments on its good fruit quality, pleasing habit of growth, and consistently good yield. It has again scored highly in this year's canning tests.

Malling Promise and Exploit, being well forward in growth, suffered severely from the frosty winds in April. Despite this, a surprising proportion of flower buds of Promise escaped damage and both varieties subsequently threw out laterals from dormant buds low down on the fruiting canes. Reports on the fruit canned this year confirm the unsuitability for canning of Malling Promise and its sister seedlings, Exploit, V, Y, and Z.

Both the Amos and New Zealand Lloyd George stocks recovered rapidly from frost damage by producing a second crop of fruiting laterals. This variety has, along with Norfolk Giant, retained its position as the premier canning berry among current commercial varieties.

Six recently selected seedlings included in the Kirriemuir trial, have had favourable reports from the canners.

Of other varieties, Malling Seedling M attracted some attention this year by its high yield at Slatefield and elsewhere, and its suitability for canning. Malling Enterprise continues disappointingly low in yield, though in quality it is considerably better than other heavier cropping varieties. Malling Landmark, despite its phenomenal yield, cannot be recommended for Scottish conditions, on account of its soft fruit, excessively spiny canes and susceptibility to Cane Spot.

Publications During the Year.

(See Section V, C260)

Part III

RESEARCH REPORTS AND REVIEWS

AMOS MEMORIAL LECTURE*

THE FRUIT TREE AND ITS ENVIRONMENT

By Sir EDWARD SALISBURY, C.B.E., D.Sc., L.LD., V.P.R.S.

Mr. Amos in whose memory this lecture was founded, in addition to being a fruitgrower whom we held in high esteem, was a man of wide interests and it is, therefore, appropriate that in envisaging the fruit tree and its environment I do so in its wider aspects.

You will recall Chesterton's story of the man who was unseen because he wore that magic cloak of invisibility woven from the warp and woof of extreme familiarity. It is the same underlying thought that engendered the adage that it requires genius to see the obvious. If, therefore, in the course of my remarks I refer to facts well known to many of those present, I shall do so in the hope of presenting them to you in a less familiar form that may, perchance, from that very fact, stimulate thought by focussing attention on the aspects that we are apt to disregard because we take them for granted.

First of all, then, let us consider in what does a fruit tree consist. We too frequently forget that the commercial fruit tree is an artificial creation of man which comprises an intimate association of stock and scion. The work at East Malling in particular has demonstrated the profound importance of the stock in determining the development of the scion, or scions, grafted upon it. This fact alone should be sufficient to emphasize to us that the overground portion of our composite organism, because it is the portion that is visible, has in the past received an undue proportion of attention. For though the shoots produce the fruit we all realize now that the stock, on which the branch system is supported and in part nourished, determines to a considerable degree at what age fruits will be produced and in some degree their quantity and quality.

But as yet we know all too little of the influence of the stock on the span of life. No one knew better than Mr. Amos the fact familiar to you all, that the quality of the fruit of many varieties, particularly marked in some, appears within any one stock to be a function of age. Was, for instance, the reason why many of our forebears placed the Ribston Pippin in a category superior to the Cox because they were comparing the fruit of mature trees of the one with fruit from immature trees of the other ? Ribston apples off young trees can be but little more than turnips.

This accretion of quality with age, though much more marked in some varieties than others, is met with alike in apples, pears and grapes and is possibly a general phenomenon. If, as some believe, this augmentation of flavour is associated with a change affecting nutrient supplies from the soil, whether macro-nutrients, micro-nutrients, or both, perhaps affected by the shoot-root ratio, it is obvious that the quality of fruit may be influenced by the type of stock upon which we graft.

Though yield alone be important we are all realizing that the maintenance of even our home markets in the face of competition is tending to become more and more dependent upon the maintenance and improvement of quality. Many of those best able to judge have paid tribute to the superiority of the English Dessert apple over those produced in other climates, but it is only if we continue to cherish the subtler features of quality that we can hope to maintain our markets in the face of overseas competition.

Let us turn to yet another aspect of the stock-scion relationship, namely, its influence upon the span of life. There has been, as you are aware, some popular suggestion that the bush fruit upon a dwarfing stock which comes into bearing early might have a shorter span than the same variety on a vigorous stock, though there is no definite proof of this and though commercial growers do not keep their trees till they fail from decrepitude, the changes connected with maturity and senescence are a long continuing process of which death is but the final phase. The acceleration or retardation of these

* Delivered at Wye College on 26th October, 1950.

processes is, therefore, probably susceptible to regulation and may well be as practically important as scientifically interesting.

We thus apprehend the stock upon which the scion is dependent as capable of being regarded as part of the environment, and a very important part, in which the scion develops. One moreover which is in considerable degree under our control.

The underground parts of the fruit tree have been shown in apple stocks to exhibit wide differences in extent and this doubtless implies differences in their facility for taking up the major nutrients and perhaps even more profound differences in their capacity to exploit trace element supplies. Despite the minute amounts of, for instance, zinc, molybdenum, manganese, or boron which the tree demands they are essential to plant life and sometimes present in amounts or in conditions which render them deficient or unavailable. Moreover in soils verging on a condition of nutrient deficiency, it will be evident that the volume of soil exploited by the root-system is a significant factor in their sufficient supply and that the extent and degree of ramification of the root system may be important in determining the quantity available. Can we then not, to some extent, mitigate the soils defects by varying the type of root system according to the high or low fertility of the soil ? For we must not forget that the nutrients we may artificially supply, since they affect the surface layers mainly and the deeper layers to a far smaller degree, cannot obviate the desirability of adjusting our root systems to the soils they are destined to exploit.

Nature has provided the tree with two very different though inter-related surroundings. The one, the air, occupied by the shoot system is a gaseous environment of remarkably constant chemical composition. The main exceptions to this generalization are the changes in moisture content of the atmosphere and accidental impurities provided by dust and smoke. The chief variables of the gaseous environment, apart from the water vapour in its various forms, are the physical changes in respect to temperature and wind.

The other environment, the soil, offers a striking contrast. It is not only a dense medium but far more complex, possessing its own atmosphere, far richer in carbon-dioxide, its soil solution, its organic and inorganic constituents, and its teeming population of microscopic plants and animals. Moreover, each of these components may be subject to wide variation both in space and in time.

In view of this great variability in the circumstances that surround the roots, it is remarkable that for so long investigation was almost confined to the scion. Indeed until Hatton provided standard, vegetatively multiplied stocks neither was accurate experimentation possible nor could the tree be adjusted to the soil. Even to-day, the facilities available in this latter aspect have been inadequately exploited. But whilst the individuality of the root systems of different types of rootstock is part of the picture, their physiological idiosyncrasies as well as their morphological distinctions are important. Professor Wallace has for instance called attention to the susceptibility of M.V to potassium deficiency, whilst M.I is susceptible to magnesium deficiency.

Because the two parts of our dual organism, namely scion and stock, may be said broadly to occupy respectively these two different environments, it might seem as if our task of adjustment were simplified. But, in fact, we know that the relation is complicated not only by the reciprocal influences of stock upon scion and scion upon stock, but by the elusive nature of compatibility, involving not merely the mechanical relations of growth but all the subtleties of physiological tolerance and balance.

The work carried out in recent years on skin grafting of human beings has shown the extreme sensitivity of the reacting tissues of a union depending for success on the physico-chemical nature of the partners in the potential graft. The experiments carried out with bridge grafting show that similar complications may obtain with respect to fruit trees. It will be recalled that Montgomery, Moore and Hoblyn showed that the plum rootstock Myrobalan B, which is compatible alike with President and Victoria, exhibits incompatibility at the Myrobalan B—President junction if the President be top-grafted with Victoria.

Thus the duality which we have artificially introduced, whilst it brings some measure of added control of culture also brings with it added complexities and these may, in plantations, be even greater than would at first sight appear since natural grafts between roots of the same species are far from infrequent and introduce an unmeasured factor in practice and a possible source of error in experimental interpretations.

Some thirty years ago I called attention to the profound influence which the presence of one plant could exert upon the root development of another, an aspect of competition that was subsequently shown to be, in part at least, due to water-soluble substances derived from the roots themselves and the action of which might differ with the species or even variety concerned. That these facts are applicable to fruit trees, as well as to the herbaceous plants studied in my laboratory, is suggested by various experimental results, but it will suffice for our present purpose to recall the recently reported experiments of Garner and Hatcher utilizing Myrobalan plum cuttings. The roots of those cuttings that were spaced nine inches apart attained between four and five times the size

of the root systems of cuttings spaced only three inches apart and it is noteworthy that this difference of root development was of the same order of magnitude whether the cuttings were manured or unmanured, or whether they were irrigated or not, suggesting that the main spacing effect was largely independent of competition for nutrients or water.

The contiguity of root systems may be expected to affect growth in two ways, firstly by competition for water and nutrients, which will manifestly be greater the more nearly the supplies of these approach to the minimum requirement, and secondly by the root secretions, which may operate equally whether the status of fertility be high or low.

In 1937, W. W. Yacum published the results of studies on the root system of the Delicious Apple, carried out in Nebraska over a period of three years, in which he showed that the nearer to the apple-trees a corn crop was cultivated the more marked was the diminution of root spread, but since the soil was of good texture and well aerated a compensatory increase of rooting depth resulted in a growth rate that was not significantly less.

The investigations of Rogers and Vyvyan on the root systems of fruit trees have not only shown the very striking individuality in this respect of different types of rootstocks but also how greatly the spread of the root system surpasses that of the branch system. Moreover, they found that this ratio of root spread to branch spread is nearly twice as great in sand as in clay.

Rogers called attention to the intermingling of the roots of adjacent trees even when these were 27 ft. apart. Peren recorded a 30 ft. root spread for a fifteen-year-old Cherry whilst the nineteen-year-old Apple tree investigated by him had a root spread of 10½ ft. It is, therefore obvious that root competition is a very real factor and that the ideal spacing of trees will represent a compromise between the severe competition that density imposes and the overheads that wide spacing would incur.

This brings me to the subject of root pruning, which the introduction of the dwarfing stock with its restricted root system has largely rendered redundant. Nevertheless, the spectacular effects upon yield which root pruning can produce makes one realize that spacing may play a not unimportant role in respect to crop yield as well as vegetative vigour.

The individuality of different varieties of apples in respect to the character of their root systems was well illustrated by the studies of L. A. Thomas on the root system of apple trees growing on their own roots. These not only show a considerable difference in the extent of the roots in such varieties as Bramley Seedling and Gravenstein compared with the small root spread of an Allsopp's Early, but also the root-system, as measured by weight, was small in relation to the stem in such varieties as Delicious and Jonathan, whereas it was large in Peasgood, Laxton's Superb and Bramley.

In some varieties there is an intensive exploitation of comparatively small soil volumes, as for example in Allsopp's Early, whereas in other varieties a much larger volume of soil is exploited far less efficiently.

All these differences in the development of the underground parts of the plant must manifestly influence the supply of water and nutrients, and though probably unimportant when the supply of these is large, will become of more and more significance as their supply becomes marginal or even deficient, and so far as those nutrient requirements are concerned which are needed in amounts of extreme diminitude, but nevertheless only occur in the soil in similarly minute amounts, the difference between failure and success might well depend upon the volume of soil exploited, and therefore upon the intrinsic quality of the root system that the variety is capable of developing. It must, therefore, be borne in mind that the absorptive surface is multiplied by a significent factor owing to the presence of root hairs, and here again, there would appear to be a variety of differences in the extent to which the known factors influencing root hair development affect the number and extent of their production.

To those, and they are still not a few, who think almost exclusively in terms of nitrogen, potassium and phosphorus, the extent of the root system may often have little significance but as soon as we turn to contemplate the trace elements, the importance of the volume of soil exploited and the total absorptive surface that the root system presents at once becomes obvious. For though the ions of, for example, zinc, manganese, copper and boron are only required in the most minute amounts, probably because they play a catalytic role, they are nevertheless, as you are aware from the investigations of Dr. Roach and Dr. Wallace, often inadequate in amount and upon the extent and degree of ramification of the root system of the fruit tree must clearly in no small degree depend their supply. In this connection it may be appropriate to mention that the effective control of zinc deficiency, causing rosette in fruit trees, which has been achieved by planting lucerne may well be due to the deep-rooted character of the leguminous plant and its intensive root system.

As already suggested, the root hairs which clothe the young roots may play an important part, for they enormously increase the area of surface contact between root and soil. For the maize plant it has been estimated that the absorptive surface of the root can be increased sevenfold by their presence. What factors are applicable to fruit trees have not, so far as I am aware, been determined

but it is relevant here to note that good root hair development with its obvious advantages is subject to environmental control and depends upon the maintenance of an optimum soil moisture that must be high enough to ensure root turgor but not so high as to cause waterlogging, since good aeration is an essential condition. And here perhaps is one of the more significant ways in which organic matter is important in the soil, because its physical properties, especially in respect to its internal surface, are such that organic material can retain a high content of moisture whilst still maintaining adequate pore space for the soil atmosphere.

Another aspect of the root hairs that must not be overlooked is that there is good evidence that some ions may be taken up, not from solution, but from the solid phase of the soil by contact exchange. In this the root hairs have a high importance with the polyuronides of their wall perhaps playing a dominant role.

The intake of nutrients has been shown to depend on respiration of the roots and hence in practice on soil aeration. Moreover, good aeration brings about an augmented absorbing surface. Roots of cherry and plum in well aerated soils are, for instance, known to penetrate to depths of from 20-26 feet. Hence it is manifest that the deeper the effective oxygen content of the soil atmosphere, the more efficiently will the nutrients be absorbed over an increased volume.

It will be recalled that Rogers and Vyvyan in their root studies of Lane's Prince Albert on various stocks compared the performance on loam of four different types, namely the very dwarfing No. IX, the very vigorous No. XVI and the vigorous and semi-dwarfing Nos. I and II. Two trees on each type of stock were investigated and, if we examine the data which these authors provide, we find that on each type of stock the greater fruit yield was furnished by the individual that had the more extended root system as judged by weight of roots extending more than 1½ metres from the trunk.

The farmer's belief in the value of the cold of winter and climatic fluctuations may have some foundation in the gaseous diffusion between soil air and atmospheric air which marked temperature changes promote. Even more, that the value of drainage may be not so much with respect to removal of water as removal of the heavy carbon dioxide gas, is suggested by the benefits that have accrued from good drainage systems even where the water table was not high.

With increase in the concentration of ions in the soil-solution there is augmented intake of nutrients but experiments have shown that the more dilute the solution the higher the proportion that is absorbed and moreover the absorption of ions is less fluctuating. So that the normal practice in the application of mineral fertilizers may produce a higher absolute intake but is probably wasteful of material, if not of labour, whereas the supply by methods of irrigation with very dilute solutions of nutrient salts is clearly not only more efficient but ensures an even ration in place of possible surfeit and subsequent decline, with considerable wastage by leaching. If the former method be economically defensible it is on practical grounds and not because it is physiologically justifiable.

The problem of the nutrition of our fruit trees has been appreciably complicated since we came to learn that in addition to the major nutrient requirements there were a number of elements no less essential, even though needed in amounts of such diminitude that it would appear almost incredible that they could determine success or failure, were it not that they almost certainly play a direct or indirect part as catalysts in accelerating essential chemical processes. In this connection we recognize that certain ions such as molybdenum become more readily available as the soil becomes more alkaline, whilst the reverse is true for the ions of manganese and boron, though for the same soil reaction it has been shown that the availability varies both with the species of plant and with the type of soil.

The important points I would emphasize are that the availability of the various nutrients differs with chemical and physical conditions and that when these are optimum for one they may be far from optimal for another.

The broad distinctions of soil types dependent on the more marked differentiations of climatic conditions are now generally recognized. We appreciate that the extreme arid climate accompanied by an upward trend of solutes, on the one hand, and on the other the climate of high precipitation with consequent downward leaching of solutes, produce respectively the saturated and unsaturated soil conditions. But I suggest that we too frequently overlook the three-dimensional pattern produced by both these processes which operate in so large a proportion of soils resulting in a stratification, or it may be a conglomeration, both horizontal and vertical, of leached and unleached strata or crumbs, presenting a diversity of media that permit the growing fruit tree to enjoy a wide range of physico-chemical conditions and thus perhaps to obtain all its nutrient requirements under favourable if not actually optimal circumstances.

In this connection I would recall the experiments carried out by Gile and Carrero in which they showed that a plant can absorb all its requirements in respect of one type of nutrient-ion through one branch of the root system alone and satisfy its needs in respect to other ions by exclusive absorption through other roots. It follows, therefore, that if within the volume of exploitation of a root system there be acid leached crumbs or strata and also unleached and perhaps alkaline crumbs or strata,

manganese and iron might, for example, be readily obtained from the one and molybdenum from the other.

In natural conditions there is normally a relatively acid surface soil more or less unsaturated in respect to nutrient ions, which has been produced by the combined action of the climate and the organisms which it supports, and this rests on a sub-soil that is relatively unleached and either of low acidity or even alkaline in reaction. When we cultivate our fruit crops, however, we tend to promote conditions of uniformity and broadcast dressings of mineral fertilizers and lime and tend to ensure a chemical as well as a physical homogeneity.

It may well be that the maintenance or encouragement of more heterogencous conditions would be beneficial. Experiments I have carried out with herbaceous species would seem to indicate a definitely beneficial effect from heterogeneous as compared with uniform distribution of soil constituents and I would suggest the possibility that the same might perhaps apply to the fruit tree. Moreover, by applying lime or mineral nutrients to alternate avenues of trees the fruit plantation lends itself to heterogeneous nutrition. It may well be that some of the spectacular benefits that accrue from placement of mineral fertilizers are an outcome of the heterogeneity it maintains.

The fruitgrower thinks of biennial fruiting of certain varieties of apple trees as one of the crosses which he has to bear, a defect in the make up of an otherwise admirable creation, but it is well for us to see this feature in its proper perspective, and to do this we must think of the apple tree, not as an artificial product of our cultivation, but as the wild progenitor, faced with normal agencies of destruction, possessing qualities by virtue of which its survival in the wild state was assured. The wild crab in common with most other species I have investigated, suffers its major mortality during the seedling stages. Seedling apples are eaten by field mice, devoured by predatory insects and attacked by various fungi.

It is a familiar feature to every grower that the enemies of the plants he cherishes gradually build up their population and there is always a lag between the development of the population of the food plant and the development of its pests and predators, and another lag between the development of the predators and the parasitic organisms which prey upon them. Imagine therefore a year in which wild crab trees produced a large crop of crab apples with a consequent abundance of apple seedlings. This large supply of apple seedlings nourishes the field mice so well that their families increase in size. It nourishes the predatory insects and these multiply rapidly also. The population of parasitic fungi is likewise quickly augmented, but owing to the lag just referred to the large population of Crab seedlings leaves a certain surplus which enables the species to survive. If similarly a large population were produced in each successive year, the high population of predators and parasites already built up from a small beginning in the previous year might completely wipe out even large populations of seedlings in subsequent years, but in fact a year of abundance in the wild crop is followed, as we know, by one, or even several years, of meagre reproduction.

Thus we find predators without a food supply requisite to their need. As a result many of them die of starvation and this diminished population is preyed upon in turn by their enemies and so we might almost describe the build up of the population of dependent organisms as turning upon itself and leading to its own destruction. The fact that a few individuals are produced during the off years may be biologically desirable from the point of view of the species as maintaining a small population of the food chain, the operation of which in reverse is so important to the survival of the major species. Thus natural selection may have imposed irregular fruiting and a concomitant physiology.

We thus see the biennial fruiting of the apple in its true perspective, as a feature evolved by the operation of natural selection as a means of protection of the species against elimination by the high population of organisms which feed upon it, so that our attempts to eliminate biennial fruiting from the apple tree, so justifiable from the point of view of its commercial exploitation, under conditions where we can afford to raise and artificially protect the offspring, are seen to be another illustration of the fact that what we consider to be a healthy and well-planned organism from the economic standpoint, is in fact an organism upon which we have imposed artificial standards.

Our concept of what in fact we regard as desirable does not correspond to what is healthy, considered as organism under natural conditions, and this I think is a very important point for us to get firmly fixed in our mind, for when we say we desire to grow healthy and robust trees, it is healthiness and vigour which we constrain by very artificial limitations, and unless we keep quite clearly in our minds that we are imposing such artificial restrictions, we may well fail to achieve that compromise between what is apparently desirable and the balanced vigour of the organism which is the true estimate of real economic efficiency. Indeed our artificial stimulation of high and repeated fruit production involves amongst other consequences a high consumption of nutrients that the proper use of mineral fertilizers can alone make good, a fact overlooked by the " muck-minded " who would " rob Peter to pay Paul " in their attempt to replace what has been lost, by compost alone.

Turning now to the climatic environment, the influence of this upon the growth and reproduction of fruit trees has been frequently considered, but for the most part the approach has been decidedly

naïve, and indeed reminds one of the statistician who set out to study the relation between weather conditions and the dates of human births. He concluded that by far the larger number of births occurred on fine days. He had obtained his weather data from the Meteorological Office and relied for the dates of births on the returns of the Registrar General. Thus the sources of his information were beyond reproach. He failed, however, to realize that in fact the dates recorded by the Registrar General are not the dates of birth but of registration. Naturally parents tend to postpone registration when the weather is wet, and wait till a fine day to do so. Hence the high degree of correlation that the statistician obtained!

Attempts to correlate the size of fruit crops with the weather of the year in which they are produced have often been no less naïve, seeing that the crop production of, for example, the apple or the plum, is not an event, but a process which involves a whole series of crucial incidents, each of which may be profoundly affected by the weather conditions and other factors that obtain at the time. Perhaps the first of these critical phases is the differentiation of the flower bud, which in some varieties of apple was shown by Gibbs and Swarbrick to occur during the last fortnight in June. Ball showed that the flower-bud initiation in certain plums takes place in late July and early August. The differentiation of the ovules and pollen occurs appreciably later than the initiation of the flower buds and for plums, investigated by Ball, this took place in January and February. It is thus apparent that for this important phase alone, the weather 8 to 10 months before the blossoms expand may be of paramount significance.

In quite general terms and ignoring the differences between varieties of the same kind of fruit, it would appear that fruit-bud differentiation occurs earlier in the apples than the plums and in the pears later still, so that we should not expect a season which suits the one necessarily to be favourable to the others. Moreover evidence has been produced at the John Innes Horticultural Institution that weather conditions which are unfavourable to apple blossom may actually be favourable to the development of parthenocarpic seedless fruits of some pears.

The importance of weather conditions at the time of flowering itself and during the critical phases of pollination and subsequent fertilization scarcely need emphasis, and it is clear that exceptional climatic conditions at any, or all, of these phases may lead to failure in crop production. The incidence of late frosts in connection with the middle of these critical phases has naturally tended to receive a good deal of attention by reason of the possibility of its control but such measures are palliative and rather in the nature of insurances, the value of which is to be assessed on economic grounds bearing in mind that the risk may easily exceed what our palliatives can control. Such devices as orchard heating and the like cannot do more than reduce by a few degrees the possible lowering of temperature and therefore it becomes a matter of the estimate of probability as to whether or not the insurance thus effected is worth while.

Short of the impracticable, extensive air-conditioning of fruit orchards our best hope of dealing with these climatic conditions may well be by evasion rather than by cure, an evasion achieved by proper selection of resistant varieties whose critical phases are either earlier or later than the normal incidence of adverse climatic conditions. If this suggestion be valid, it is apparent that we need far more knowledge regarding microclimatic conditions in orchards and concerning the differences between varieties, particularly respecting the precise periodicity of their critical phases of development.

A word may here be said concerning shelter. Whilst observation give support to the view that windbreaks may be of great importance in some seasons and in certain localities, there is little knowledge concerning their precise significance, the more so that, according to the meteorological conditions and topography, the windbreak may be beneficial in some respects and harmful in others. The beneficial effects during a wind frost may be spectacular and a windbreak may be a valuable means of deflecting cold air drainage. In summer also the shelter belt may materially reduce evaporation to a horizontal distance that may be more than ten times the height of the windbreak. On the other hand the loss of water from the soil which the shelter-belt transpires may, in low velocities of wind, more than offset the reduction of evaporation from the soil and the fruit plantation itself. The greater the average wind velocity the more likely is the wind-break to be efficacious but there is need of more exact data on this subject and also on the species of trees that are most effective as a protection. The remarkable amount of shelter that can be provided by wire netting bears witness to the importance of the permeable windbeak which by the turbulence effects it creates may be said to cause the air currents to check their own velocity. Poplars that appear attractive by reason of the rapidity of their growth, are in reality quite unsuitable by reason of the extent of their root systems that exploit the soil beneath as rapidly as the shoot system exploits the air above. For the reasons already adumbrated the light-canopied foliage and tracery of twigs of such wind tolerant trees as Birch and Rowan constitute an obstacle out of proportion to their density whilst possessing root-systems that are intensive rather than extensive.

The conditions which determine fruit-bud initiation are associated with carbohydrate accumulation and apparently a high proportion of starch and sugar in relation to the supply of mineral nutrients.

Such a high carbohydrate-nitrogen ratio appears to be a necessary condition of the internal environment in which fruitfulness can be achieved. There is experimental evidence from plants other than fruit trees that renders it probable that a chemical substance that we may term a reproductive hormone is involved but this would seem to operate only under suitable conditions. Moreover, as Gregory has pointed out, there are theoretical grounds that suggest the reproductive hormone may be convertible into the vegetative and vice-versa.

Root pruning, which changes the balance by reducing the nutrient intake from the soil and thus increasing the proportionate amount of carbohydrate production by the foliage, can effect a most spectacular conversion from the vegetative to the reproductive state, whilst severe pruning can produce the reverse condition. Nevertheless, it has been shown that though root pruning of a well-grown apple can induce fruitfulness the root pruning of seedling apples will not bring about precocious fruit production but on the contrary will delay maturity, a conclusion in harmony with the delaying effect of competition on flower production in wild species, e.g. *Trollius*.

The larger leaf area of fruiting spurs in the " off season " of a biennial fruiting apple is in no degree an inconsistent fact and the larger carbohydrate production which this implies may be a requisite condition for the flower differentiation of the " on " year that follows. It is moreover in the leaves that the first stage of the chemical reactions leading to the reproductive hormone is initiated. A year of drought, perhaps by increasing the proportion of roots which die annually, a feature to which Rogers has called attention, may produce the same effect as root pruning but that a copious differentiation of flower buds may not imply a good fruit harvest is only too familiar. The fact that flower buds are formed in every season, though in such fluctuating numbers, shows that the reproductive hormone is formed each year but either in very different amounts or in conditions favourable or unfavourable to its operation. In either circumstance it is the internal environment of the fruit tree that must be held responsible.

Flower initiation, though an essential, determines only the potential maximum and of this only a very small percentage is destined to form fruit even when a heavy crop is borne. So that the later critical phases are in some respects more significant. In the first fruit drop direct competition between the neighbouring flowers may, especially in pears, be of paramount importance. In the second drop all fruits are shed in which the critical phases of pollination and fertilization have not been successfully achieved, whilst in the so-called June drop, competition for nutrients between adjacent fruits probably plays a major role.

The attempts to retain fruits that would otherwise be shed, by the use of spraying growth regulating substances, or to reduce the tendency towards biennial bearing, by drastic thinning of blossoms, are important investigations which may become of practical value, but may be even more significant as increasing our apprehension of the problems involved. They alike tend to modify effects, rather than the causes themselves, and it may well be that investigations on the application of nitrogenous or other fertilizers during the pre-differentiation period, say mid or early May, might by influencing causes rather than effects produce a more satisfactory means of combating biennial bearing.

Every healthy organism may be said to be a suitably balanced system in which the processes of vegetative increase and maintenance of reproduction and even resistance to the normal incidence of diseases and pests, are all carried on without permanent injury or even loss of vigour. But when we claim that we desire to grow healthy fruit trees let us not forget that our concept of what is a healthy organism is one that is out of balance in the sense that it is a fruit factory with an abnormal emphasis on the reproductive phase. This implies readjustment in almost every other aspect of the organism's activity and hence the need for that exhaustive study of fundamental physiology without which such adjustment will be based on luck rather than on judgment.

I have endeavoured this afternoon to adumbrate the diversity of the aspects from which the environment of the fruit tree can be considered ; an external physical environment that is dual in character, each part reacting on the other and subject to wide variations both in time and space ; an internal environment that is no less important, dependent for its nature in no small degree upon the heritable characters of the component parts of the organism we have created.

Fruit culture is a problem in practical ecology and it is only by an appreciation of the integrated pattern to which all these variables contribute that we can hope to see our objectives in their true perspective.

We can endorse the plea of Captain Wellington, in the first Amos Lecture, for the elimination of control measures by the establishment of more healthy plants.

But only the closest and most sympathetic co-operation between the skilled practice of the grower and the basic knowledge of the scientific investigator can achieve that new equipoise that the artificial conditions we impose necessitate.

Such an attitude will at least deserve success and is the most likely means to ensure it.

POMOLOGY

THE EFFECT OF NETTING AND HESSIAN ANTI-FROST SCREENS AND OF BRICK WALLS ON AIR TEMPERATURES

By W. S. ROGERS and A. BERYL BEAKBANE

Introduction.

It is well known that screens of various materials, laid over plants in frosty periods, can, to some extent, mitigate frost damage. It is also a tradition among gardeners that string netting helps to ward off the effects of spring frosts on the blossom of wall-trained trees. Nevertheless, little experimental information on these matters is available.

A small experiment with string netting was carried out in the walled garden of Bradbourne House in the spring of 1947, and one using hessian instead of netting in 1948. A small further study was made of the effect of a wall in 1949. Large hessian screens were also used over some mature bush trees in 1947, 1948 and 1949.

The use of string netting as an anti-frost screen, 1947.

The netting used was made of $\frac{1}{32}$ inch diameter brown string, with a 1 inch square mesh, and was in fact some of the old fishing net commonly sold for garden purposes.

A single layer of this netting, 30 feet long, was hung from near the top of a 13 foot red brick wall, facing south, in the large Bradbourne walled garden. The netting remained in position day and night. One-year-old peach trees were trained against the wall, but they could not have had an appreciable effect on the trial as they were so small.

The six 10 inch Six's type maximum and minimum thermometers available were placed at a height of 4 feet 6 inches on the wall, both beneath and outside the net, and also on posts 5 feet away from the wall, at positions indicated in Fig. 1. These thermometers, which were graduated in single

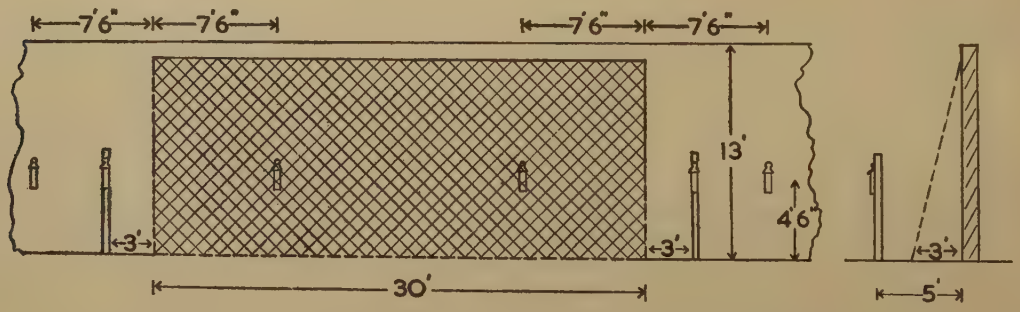


FIG. 1.

Front and end elevations showing arrangement of netting and thermometers on wall.

degrees, had bulbs $4\frac{3}{4}$ inches long $\times$ $\frac{3}{16}$ inch diameter, and were found on test to be accurate and comparable. The small conventional lid covered an area of $1\frac{1}{2} \times 3$ inches above the top of the bulb. Thus the bulbs were practically unscreened, except at the back, and it is likely that the temperatures recorded under the conditions stated are closer to those of exposed buds and twigs on and near the walls than to the air temperatures which would have been recorded by fully screened thermometers.

Results.

The thermometers were read daily at 9 a.m. G.M.T., from 3rd April to 23rd May, 1947. A summary of the results is shown in Table I.

Netting effect. Table I shows that the netting had no effect on minimum temperatures, either on the eight nights when the temperature fell to 32° F. or lower, or on all nights taken together. The

TABLE I.

NETTING ANTI-FROST SCREEN TRIAL, 1947. TEMPERATURE, °F.

		On posts 5 ft. away from wall.	On wall.	
			Outside net.	Beneath net.
Mean for days on which there was an air frost at night (8)	Max.	70·6	74·8	74·0
	Min.	29·8	31·0	30·9
Mean for all readings, 3rd April to 23rd May, 1947	Max.	71·5	73·6	74·1
	Min.	41·2	41·3	41·4

Where statistical analyses showed differences to be not significant at the P = 0·05 level, the means are bracketed.

maximum temperatures were also not appreciably affected by the netting. These results are not surprising since the netting was found, by calculation, to impede only 6·25 per cent of radiation.

Wall effect. The difference in minimum temperature recorded on the wall and 5 feet away from it, taking all nights together, was negligible. On frosty nights it was of the order of 1° F., and was not significant.

Greater differences in maximum temperatures were found. Over the whole period the mean maximum temperature was 2·1° F. higher on the wall than 5 feet away, and on days preceding frosty nights, 4·2° F. higher; these were usually sunny days.

The use of hessian as an anti-frost screen, 1948.

Light industrial hessian was used, having twelve threads to the inch in both directions. When new it was nearly opaque, but after some weeks exposure out-of-doors the threads shrank considerably and the opacity was only of the order of 75 per cent. Strips were hung in a single layer from a pole framework beside a wall in the smaller of the Bradbourne walled gardens, over five-year-old fan-trained apricots (Fig. 2 and 3). This wall, like the other, faced south. The screens were raised during the day and lowered at night, except during severe frosts, when they were left down all day. Six's thermometers were placed beneath and outside two screens and also on posts 5 feet away from the wall, making a total of 6 thermometers as in Trial I. The width of the hessian covers varied according to the size of the tree; and those under which temperatures were taken were 20 feet and 12 feet wide respectively.

Results.

The thermometers were read daily at 9 a.m. G.M.T., from 13th March to 20th May, 1948. The readings showed that there was a temperature gradient from one end of the wall to the other, probably due to a curve in the wall at the eastern end. A covariance correction was therefore used for the distance of the thermometers from the east end of the wall assuming a linear temperature gradient.

Hessian screen effect. Table II shows that the minimum temperature was higher beneath the hessian screens both on nights when there was an air frost and when all nights were taken together. The minimum temperature beneath the screens was consistently about 5° higher on frosty nights than the temperature outside the screens. The maximum temperatures were not affected by the screens, but it should be pointed out that the maximum normally occurred while the screens were raised.

Wall effect. The differences in minimum temperature on the wall and 5 feet away were significant though small, both on frosty nights and when all nights were taken together (Table II). On frosty nights the minimum on the wall was 0·7° F. higher than 5 feet away.

Although the mean maximum temperature on the wall was some 7·0° F. higher than 5 feet away, the difference did not reach statistical significance, in contrast with Trial I—a reflection of the many factors causing variability in maximum temperature. The greatest difference recorded was 14·2° F.

The rate of cooling of the wall was studied in 1949. In April a double mercury-in-steel thermograph with exposed bulbs at 4 feet above soil level, was set up near the wall. The records between 8th April and 19th May showed that the large daytime differences in temperature between the air near the wall and at 5 feet away decreased rapidly in the afternoon from about 2 p.m., and that on

TABLE II.

HESSIAN ANTI-FROST SCREEN TRIAL, 1948. TEMPERATURE, °F.

		On posts 5 ft. away from wall.	On wall.	
			Outside screen.	Beneath screen.
Mean for days on which there was an air frost at night (20)	Max.	73·3	80·9	80·5
	Min.	29·4	30·1	34·9
Mean for all readings, 13th March to 20th May, 1948	Max.	75·9	82·9	80·6
	Min.	37·1	37·5	41·6

Where statistical analyses showed differences to be not significant at the P = 0·05 level, the means are bracketed.

warm nights there was no difference in temperature between these two positions, but on cold nights the heat from the wall kept the air near it a little warmer than the air at 5 feet away. The mean difference between the minima recorded on the wall and at 5 feet away from it, during the period 8th April to 19th May, was 1·35° F., the wall being the warmer. Temperatures during two typical sunny days followed respectively by a warm and a cold night are given in Fig. 4.

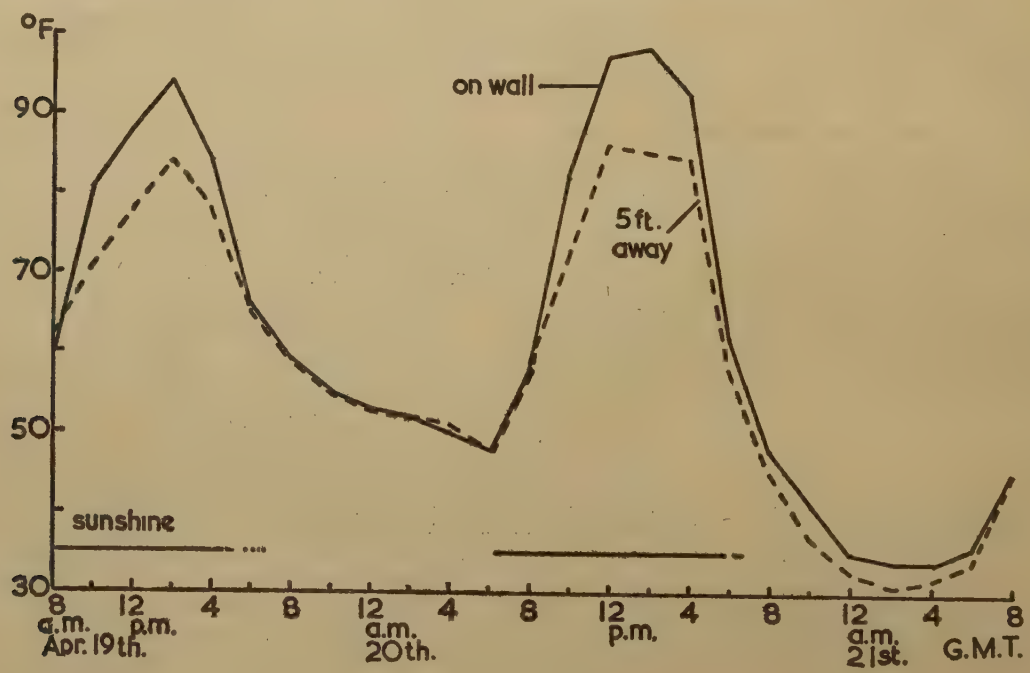


FIG. 4.

Temperatures recorded by exposed-bulb thermometers at a height of 4 feet, on a wall and 5 feet away from it.

Screening mature apple trees.

In certain experiments on biennial bearing on thirty-year-old Miller's Seedling, it was especially important that results of treatments carried out in the previous year should not be interfered with by frost damage to the blossoms.

Accordingly hessian anti-radiation screens were placed over six whole trees, including the most important experimental treatments, on any night when frost was expected, during the blossom seasons of 1947, 1948 and 1949. The screens consisted of frameworks made of wooden posts, with metal piping cross pieces, over which hessian sheets could be pulled when required.

The general appearance of the framework is shown in Fig. 5. The corner posts were 16 foot chestnut hop-poles, sunk about 18 inches into the soil. Cross pieces consisting of 1½ inch light iron piping were fixed as shown, forming a framework about 14 feet 6 inches square and 14 feet high. Wooden struts, placed diagonally outwards, to the top of each corner post, supported the framework against wind. A number of wires across the top helped to prevent the hessian from sagging.

One large hessian sheet, about 45 feet by 15 feet in size, was arranged so that it could be pulled over the top with cords, so covering the top and two sides. Two smaller sheets, about 15 feet square, were arranged to hang over the remaining sides. Thus the sheets masked the tree completely and prevented radiation (Fig. 6). They also checked the wind to some extent, though it was not expected that they would give complete protection against wind frosts.

The hessian sheets were placed in position on any evening when a warning of air frost of more than 1 or 2° F. was received from the Meteorological Office ; and they were removed by day. Thermographs and maximum and minimum thermometers in rough screens, consisting of apple boxes, were placed at a height of 4 feet 6 inches in comparable positions, facing north, beside covered and uncovered trees.

As it happened, no very severe spring frosts were experienced in any of these years, at the level of this plantation. It was, however, found that the air temperature was higher within the screens on radiation nights. On one night the minimum air temperature outside the hessian screen was 28° F., and inside, 32° F., a difference of 4°.

On other frosty nights the differences were smaller, usually of the order of 1 or 2° F. It was evident that these screens had less effect than the hessian screens on walls, on frosty nights. This is doubtless due to the much larger potential cooling surface of hessian in relation to the available "warming area" (the soil covered). The surface of hessian exposed to cooling in the large screens is about five times that of the "warming area" of soil ; whereas in the case of the wall screens the hessian area is *less* than that of the wall and soil covered. Thus the efficiency of box-like hessian screens, used over isolated trees, will decrease as they become taller in relation to the area covered.

Certain small trees in pots, used in controlled freezing experiments in the frost laboratory at East Malling, are now sheltered from natural frost in the blossom period each year by hessian covers placed over low frameworks. In this case the ratio of exposed hessian to soil is only about two to one, and the efficiency is accordingly relatively high.

Discussion.

It is clear that the belief that thin netting will protect wall-trained trees from frost is a myth. Only if many thicknesses were used could it have any anti-radiation effect. Netting might usefully reduce high wind speeds ; but this effect was not tested.

Hessian screens, on the other hand, have been shown to be very effective in protecting wall trees from frost. A practical point shown in the trial is that strong hems at the edges of the screens are important to protect them from fraying or tearing.

The heating effect of walls, on objects near their sunny side, is great on sunny days, but relatively small at night, owing to rapid heat losses. It should be noted, however, that walls themselves act as effective radiation screens from half the sky, for objects upon them. In this trial, they also screened the thermometers 5 feet away from them from about one-third of the sky, thus probably reducing the differences in minimum temperature. Just as the effect of the shadow of a wall is real and important by day, so the effect of the "shade" of a wall, or any tall object, against radiation to the sky at night will extend to some distance away from it. The ground at a distance from a wall or fence equal to its height will be shielded from about one-quarter of the sky.

Such effects may, of course, be overwhelmed by an influx of cold air, causing devastating cooling by conduction ; but on the other hand, there are many occasions when the reduction in cooling rate and the higher minimum temperature given by anti-radiation screens will save plants from frost damage.

Acknowledgements.

The writers acknowledge with thanks the help of Mr. F. H. Villiers in erecting the screens and of Mr. D. W. P. Greenham and other colleagues in recording the temperatures.

Summary.

1. A single layer of string netting, hung from near the top of a brick wall, had no effect on air temperatures near the wall, either on frosty or other nights.

2. Anti-frost screens of light hessian, on the other hand, gave useful protection from frost. The mean minimum air temperature beneath them was 4·8° F. higher than on an unscreened wall, on frosty nights.

3. The wall itself, in the absence of screening, caused a small (0·7° F.) but significant increase in minimum temperature over that at 5 feet away, on frosty nights, in 1948. In 1947 the difference, though larger and in the same direction, was not significant.

The maximum temperature on the wall was higher than that 5 feet away. The mean difference from 3rd April to 23rd May, 1947, was 2·1° F.

4. Thermograph studies showed that although the maximum temperature on the wall was usually much higher than that 5 feet away, rapid cooling from mid-afternoon onwards resulted in the differences being relatively small on cold nights.

5. Box-like hessian screens over isolated mature trees, usually gave temperature increases of 1 or 2° F. above that in unscreened trees on frosty nights. The greatest difference recorded was 4° F. It is shown that such screens cannot be as effective as those hanging on walls.

Fig. 3

Fig. 2

Hessian anti-frost screens over apricot trees, spring, 1948, showing also the light pole framework used to keep the hessian away from the tree. A thermometer can be seen in Fig. 2.

[face p. 64

FIG. 5.
Framework for hessian anti-frost screen to protect a tree from spring frost damage, April, 1948.

FIG. 6.
Hessian anti-frost screen over an apple tree, April, 1948.

THE EFFECT OF CERTAIN GROWTH-PROMOTING SUBSTANCES UPON FROST-DAMAGED APPLE FLOWERS

By IRENA MODLIBOWSKA

Introduction.

Fruit set in apples is largely determined by fertilization and embryo development. These processes are believed to stimulate the development of the fruit by means of some as yet unknown growth substances. When frost kills the styles or embryos the formation of these substances is usually prevented, and the fruit does not develop.

Gardner and Marth (1935), Green (1943) and Hilton (1944) attempted to substitute for these natural hormones, substances known to stimulate parthenocarpic development in tomatoes. They did not succeed, however, in producing seedless apples. Swarbrick (1947) sprayed frost-damaged apple fruitlets in the orchard with a mixture of four growth substances considered most effective on tomatoes : α-naphthalene-acetic acid 5 p.p.m., 2 : 4-dichlorophenoxy-acetic acid 5 p.p.m., indole-butyric acid 5 p.p.m. and β-naphthoxy-acetic acid 30 p.p.m. Cox's Orange Pippin showed no response, but Miller's Seedling developed small fruits.

In the spring of 1950 a study was made, at East Malling in collaboration with Professor R. L. Wain of Wye College, on the effect of twenty-six organic acids upon the recovery of frost-damaged apple blossoms and upon setting. These substances were selected on the basis of their biological activity as indicated by several tests, e.g. parthenocarpy in tomatoes, epinasty, *Avena* coleoptile test, oat cylinder test, Went's pea test, and included α-(2-naphthoxy) propionic acid found by Osborne (1949) to induce parthenocarpy in certain pears.

Material and Methods.

The experiments were carried out on small pot trees of Cox's Orange Pippin and Ellison's Orange grown in insect-proof glasshouses to prevent insect pollination. The flowers were not emasculated, and both self-pollinated and cross-pollinated flowers were tested.

The trees were brought into the controlled temperature frost room and exposed to temperatures sufficiently low to damage critically a high proportion of the flowers (usually ½ to 1½ hours at −3° C.). The following day all flowers were examined, labelled and classified according to the degree of frost damage. In this paper the term " severely damaged " (S) refers only to critically damaged flowers, i.e. those with brown discoloration at the base of the styles. Flowers classified as " lightly damaged " (L) were not discoloured, but commonly had loose " skin " on the ovary. Such damage normally heals quickly.

The flowers were sprayed with growth substances on the same day. These were applied with an atomizer to the base of the styles and to the surface of the ovary of each flower and also to the base of its pedicel, thus ensuring proper wetting. The control flowers were sprayed with distilled water and 0·2 per cent Estol H—the wetter used with all the sprays. The compounds and concentrations tested are shown in Table I. They will be referred to by number for brevity.

Experiment 1. Cox's Orange Pippin.

Three trees of Cox's Orange Pippin were exposed at full bloom to low temperature which critically damaged about 45 per cent of the flowers. Eight growth regulating substances (Nos. 1 to 8) at 100 p.p.m. and a control spray No. 9 were applied to each tree. They were sprayed on marked flowers damaged to similar degrees. The flowers were all self-pollinated. The record taken a fortnight later (Table II) showed that almost all flowers on the control spurs and in treatment No. 6 had abscissed by that time, and that more " severely damaged " flowers dropped in each treatment (average 60·1 per cent) than " lightly damaged " ones (41·7 per cent). Further, flower drop control was most effective with substances Nos. 3 and 8 ; in the first case only 3·5 per cent and in the second 7 per cent of the flowers had abscissed. Some swelling of " lightly damaged " flowers was induced by sprays No. 2 (15·8 per cent), No. 1 (14·6 per cent) and No. 4 (14·3 per cent).

Three weeks after treatment most slightly swollen flowers were obtained with sprays Nos. 1 and 2. The " lightly damaged " flowers sprayed with substances Nos. 3 and 8 were still firmly attached in about 83 per cent of the cases, while only about 41 per cent of the " severely damaged " flowers with discoloured styles were still on the trees. During the following three weeks shedding of flowers proceeded quickly and all had dropped by six weeks after spraying.

Table I.

Growth-promoting substances tested and their serial number.

No. 1.	α-phenoxypropionic acid (sodium salt) 100 p.p.m. + 0·2 per cent wetter, Estol H.
2.	α-(2 : 4-dichlorophenoxy)-n-butyric acid (sodium salt) 100 p.p.m. + 0·2 per cent wetter, Estol H.
3.	(2-naphthoxy) acetic acid (sodium salt) 100 p.p.m. + 0·2 per cent wetter, Estol H.
4.	α-(2-naphthoxy) propionic acid ,, ,, 100 ,, ,, ,, ,, ,, ,,
5.	2-naphthoxy *iso*butyric acid ,, ,, 100 ,, ,, ,, ,, ,, ,,
6.	2-naphthoxy phenylacetic acid ,, ,, 100 ,, ,, ,, ,, ,, ,,
7.	α-(2-naphthoxy)-n-butyric acid ,, ,, 100 ,, ,, ,, ,, ,, ,,
8.	1-naphthylacetic acid ,, ,, 100 ,, ,, ,, ,, ,, ,,
9.	distilled water ,, ,, ,, ,, ,,
10.	phenoxyacetic acid ,, ,, 100 ,, ,, ,, ,, ,, ,,
11.	(phenoxy) phenylacetic acid ,, ,, 100 ,, ,, ,, ,, ,, ,,
12.	α-phenoxy *iso*butyric acid ,, ,, 100 ,, ,, ,, ,, ,, ,,
13.	β-(phenoxy) propionic acid ,, ,, 100 ,, ,, ,, ,, ,, ,,
14.	3-phenoxy-n-butyric acid ,, ,, 100 ,, ,, ,, ,, ,, ,,
15.	α-(phenoxy)-n-butyric acid ,, ,, 100 ,, ,, ,, ,, ,, ,,
16.	4-phenoxy-n-valeric acid ,, ,, 100 ,, ,, ,, ,, ,, ,,
17.	5-phenoxy-n-caproic acid ,, ,, 100 ,, ,, ,, ,, ,, ,,
18.	6-phenoxy-n-heptoic acid ,, ,, 100 ,, ,, ,, ,, ,, ,,
19.	α-(2-chlorophenoxy) propionic acid (sodium salt) 50 p.p.m. + 0·2 per cent wetter, Estol H.
20.	α-(4-chlorophenoxy) propionic acid ,, ,, 50 ,, ,, ,, ,, ,, ,,
21.	α-(2:4-dichlorophenoxy) propionic acid ,, 25 ,, ,, ,, ,, ,, ,,
22.	α-(2-methyl-4-chlorophenoxy) propionic acid (sodium salt) 25 p.p.m. + 0·2 per cent wetter, Estol H.
23.	α-(2:4:5-trichlorophenoxy) propionic acid ,, ,, 25 ,, ,, ,, ,, ,, ,,
24.	α-(1-naphthoxy) propionic acid ,, ,, 100 ,, ,, ,, ,, ,, ,,
25.	2:4-dichlorophenoxy-phenylacetic acid ,, ,, 100 ,, ,, ,, ,, ,, ,,
26.	1-naphthoxy-phenylacetic acid ,, ,, 100 ,, ,, ,, ,, ,, ,,
27.	1:2:3:4-tetrahydro-1-naphthoic acid ,, ,, 50 ,, ,, ,, ,, ,, ,,
28.	distilled water ,, ,, ,, ,, ,,

Table II.

Effect of growth-promoting substances on frost-damaged flowers of Cox's Orange Pippin.

Substance No.*	Flowers.		Percentage of flowers (or fruitlets) remaining.			
			14 days after spraying		36 days after spraying.	
	Category.	Number.	Swollen.	Unswollen.	Swollen.	Unswollen.
1	L†	35	14·6	85·4	5·7	5·7
	S‡	*24*	*nil*	*66·7*	4·2	*nil*
2	L	38	15·8	79·0	7·9	5·3
	S	*25*	*nil*	*32·0*	*nil*	*nil*
3	L	32	nil	96·8	nil	18·5
	S	*27*	*nil*	*96·2*	*nil*	*18·5*
4	L	28	14·3	57·1	nil	nil
	S	*24*	*nil*	*58·3*	*nil*	*nil*
5	L	27	nil	14·8	nil	nil
	S	*32*	*nil*	*6·3*	*nil*	*nil*
6	L	29	nil	17·3	nil	nil
	S	*28*	*nil*	*nil*	*nil*	*nil*
7	L	30	3·3	23·3	—	—
	S	*25*	*nil*	*8·0*	—	—
8	L	39	5·1	89·7	nil	5·1
	S	*23*	*nil*	*91·3*	*nil*	*nil*
9 (control)	L	37	nil	8·1	nil	nil
	S	*25*	*nil*	*nil*	*nil*	*nil*

* See Table I. † L = Light damage. ‡ S = Severe damage.

In this trial substances Nos. 1 (α-phenoxypropionic acid) and 2 (α-(2 : 4-dichlorophenoxy)-n-butyric acid) were the most promising. No. 1 stimulated some slight development even in a flower with discoloured styles.

Experiment 2. Ellison's Orange.

For the second experiment, the variety Ellison's Orange was chosen, since this is less liable to shed its fruitlets than Cox's Orange Pippin. Six trees were used and the flowers self-pollinated. On the day following freezing, when the growth substances were applied, only about half of the flowers were open and the other half still in the bud stage. The latter were sprayed on the whole exposed surface. Thus the effect of growth substances at these two stages of floral development was tested.

Eighteen substances were tried (Nos. 10 to 27) each on over 100 flowers, usually on a random branch on three of the six experimental trees.

The record taken fifteen days after spraying (Table III) showed that most of the flowers with discoloured styles had abscissed by that time. Only spurs sprayed with substances Nos. 25, 23 and 19 had a high proportion, 75 per cent, 67 per cent and 61 per cent respectively, of " severely damaged " flowers still attached to the bourses, although not swelling. Abscission of " lightly damaged " flowers was less than that of " severely damaged " ones. Some flowers in all treatments but one (No. 23) showed slight initial swelling. This was most frequent in treatments No.18 (47 per cent) and No. 12 (38 per cent). The control spurs were third with 36 per cent of initially swollen flowers. Treatment No. 15 was conspicuous for the persistence of healthy white petals on swollen and abscissing fruitlets.

During the following three weeks abscission was heavy among both unswollen and swollen fruitlets. Growth substances Nos. 25, 19 and 23 were still most effective in delaying abscission of flowers. Fruitlets in treatment No. 25 showed most swelling (16 per cent) at that time.

The final crop amounted to only one fruit each from treatments Nos. 11, 13, 16 and 19, i.e. about 1·5 per cent of the original flowers, and two fruits (2·1 per cent) from treatment No. 12. The fruits were of large size, but half of them were slightly elongated at the calyx end. One fruit was seedless. Each of the others contained one good seed. Flowers sprayed with substance No. 25 developed two tiny fruits (about 1 cm. in diameter) with only small flat seeds. Substances Nos. 19 and 25 were most effective in delaying abscission. There was no noticeable effect upon foliage and extension growth.

Experiment 3. Ellison's Orange.

In this experiment those flowers which were open before freezing, amounting to 36 per cent of the total, were pollinated by Cox's Orange Pippin. The following growth substances were selected for test : Nos. 1 and 2, which had induced most swelling on Cox's Orange Pippin, and Nos. 12 and 18, which had shown most promise the fortnight after application to flowers of Ellison's Orange. These substances were applied either alone or together with substance No. 8, which was efficient in delaying floral abscission on Cox without, however, initiating swelling.

Three pot trees were used. Each treatment was applied to one branch on each tree, i.e. on an average to 63 flowers, 59 per cent of which had discoloured styles due to frost treatment. At the time of treatment 40 per cent of the flowers were open, 36 per cent had shed their petals and 24 per cent were unopened.

Sixteen days after spraying initial swelling of fruitlets was observed in all the treatments save No. 2 applied alone (Table IV). By the addition of No. 8 to No. 2, a 7 per cent swelling was obtained, while when No. 8 was added to No. 12 the proportion of swollen fruitlets increased from 8 per cent to 35 per cent. The highest amounts of swelling (40·7 per cent.) were obtained with No. 1 applied alone and with No. (18 + 8). A high proportion of fruitlets on on of the three branches used as controls also showed swelling.

Thirty-two days after spraying all but three of the severely damaged flowers had abscissed without swelling. In Category L, most of the unswollen, and half of the swollen flowers were also shed. The effect of substance No. 8 added to the other substances was still pronounced. In this Category, the percentage of fruits harvested at 130 days was highest in the controls ; however, the four fruits were all borne on one branch, suggesting that the flowers might have suffered rather less damage than the remainder. The differences in the number of fruits reaching maturity after treatment with Nos. 12 and 18 on the one hand and with Nos. (12 + 8) and (18 + 8) on the other, give some slight indication that No. 8 may have increased the effectiveness of the other two compounds. The numbers are too small to allow of conclusions being drawn at this stage.

The percentages of flowers treated at different stages that showed subsequent swelling were : buds, 27 per cent ; open flowers, 31 per cent ; flowers whose petals had fallen, 21 per cent.

Table III.

Effect of growth-promoting substances on frost-damaged flowers of Ellison's Orange.

Substance No.	Flowers.		Percentage of flowers (or fruitlets) remaining.					
	Category.	Number.	15 days after spraying.		35 days after spraying.		146 days after spraying.	
			Swollen.	Unswollen.	Swollen.	Unswollen.	Fruits.	Good seeds per fruit.
10	L	129	17·8	13·9	4·6	nil	nil	—
	S	*22*	*nil*	*nil*	*nil*	*nil*	*nil*	—
11	L	79	20·2	8·9	8·9	1·3	1·3	1
	S	*33*	*nil*	*nil*	*nil*	*nil*	*nil*	—
12	L	94	38·3	3·2	6·4	nil	2·1	0·5
	S	*32*	*nil*	*nil*	*nil*	*nil*	*nil*	—
13	L	61	32·8	11·5	8·2	1·6	1·6	1
	S	*34*	*nil*	*nil*	*nil*	*nil*	*nil*	—
14	L	89	16·9	7·9	3·4	nil	nil	—
	S	*25*	*nil*	*8·0*	*nil*	*nil*	*nil*	—
15	L	94	14·9	35·1	3·2	2·1	nil	—
	S	*17*	*nil*	*29·4*	*5·9*	*17·7*	*nil*	—
16	L	83	20·3	19·3	3·6	nil	1·2	1
	S	*39*	*nil*	*nil*	*nil*	*nil*	*nil*	—
17	L	111	18·0	8·1	5·4	2·7	nil	—
	S	*34*	*nil*	*2·9*	*nil*	*2·9*	*nil*	—
18	L	62	46·7	3·2	12·9	nil	nil	—
	S	*40*	*nil*	*nil*	*nil*	*nil*	*nil*	—
19	L	54	3·7	90·7	1·9	37·0	1·9	1
	S	*44*	*nil*	*61·3*	*nil*	*15·9*	*nil*	—
20	L	48	18·7	12·5	10·4	2·1	nil	—
	S	*46*	*nil*	*8·7*	*nil*	*nil*	*nil*	—
21	L	37	27·0	37·8	5·4	nil	nil	—
	S	*53*	*nil*	*18·9*	*nil*	*nil*	*nil*	—
22	L	31	3·2	77·4	3·2	16·1	nil	—
	S	*41*	*nil*	*9·8*	*nil*	*2·4*	*nil*	—
23	L	44	nil	79·5	nil	34·1	nil	—
	S	*49*	*nil*	*67·3*	*nil*	*12·2*	*nil*	—
24	L	58	31·0	1·7	10·3	*nil*	*nil*	—
	S	*82*	*nil*	*nil*	*nil*	*nil*	*nil*	—
25	L	50	20·0	74·0	16·0	38·0	4·0	0
	S	*65*	*nil*	*75·4*	*nil*	*20·0*	*nil*	—
26	L	96	35·4	8·3	11·5	6·3	nil	—
	S	*42*	*nil*	*2·4*	*nil*	*2·4*	*nil*	—
27	L	24	25·0	16·7	12·5	12·5	nil	—
	S	*34*	*2·9*	*nil*	*nil*	*nil*	*nil*	—
28 control	L	107	36·4	11·2	12·1	nil	nil	—
	S	*91*	*nil*	*44·0*	*nil*	*nil*	*nil*	—

TABLE IV.

EFFECT OF GROWTH-PROMOTING SUBSTANCES ON FROST-DAMAGED FLOWERS OF ELLISON'S ORANGE.

Substance No.	Flowers.		Percentage of flowers (or fruitlets) remaining.						
	Category.	Number.	16 days after spraying.		32 days after spraying.		130 days after spraying.		
			Swollen.	Unswollen.	Swollen.	Unswollen.	Fruits: No.	Fruits: Per cent.	Good seeds per fruit.
1	L	27	40·7	59·2	33·3	nil	1	3·7	1
	S	*44*	*nil*	*100·0*	*nil*	*nil*	*0*	*nil*	–
(1+8)	L	23	26·1	56·5	17·4	13·0	1	4·3	7
	S	*50*	*nil*	*64·0*	*nil*	*nil*	*0*	*nil*	–
2	L	29	nil	44·8	nil	nil	0	nil	–
	S	*16*	*nil*	*50·0*	*nil*	*nil*	*0*	*nil*	–
(2+8)	L	28	7·1	89·3	3·6	3·6	0	nil	–
	S	*27*	*nil*	*70·4*	*nil*	*nil*	*0*	*nil*	–
12	L	24	8·3	nil	8·3	nil	0	nil	–
	S	*46*	*nil*	*nil*	*nil*	*nil*	*0*	*nil*	–
(12+8)	L	26	34·6	34·6	19·2	nil	1	3·8	8
	S	*33*	*nil*	*39·4*	*nil*	*9·1*	*0*	*nil*	–
18	L	26	30·7	3·9	15·4	nil	0	nil	–
	S	*48*	*nil*	*nil*	*nil*	*nil*	*0*	*nil*	–
(18+8)	L	27	40·7	3·7	25·9	nil	3	11·1	6
	S	*43*	*nil*	*14·0*	*nil*	*nil*	*0*	*nil*	–
9 control	L	28	35·7	3·6	21·4	nil	4	14·3	5
	S	*42*	*2·4*	*nil*	*nil*	*nil*	*0*	*nil*	–

Fruitlets from the younger flowers abscissed, however, later in the season, so that all the mature fruits but one developed from flowers sprayed after their petal-fall. The one fruit that originated from an open flower contained one seed only. Two fruitlets without any good seeds were noted but these abscissed by the end of June. No fruit was found without any seeds. In the large but flat seeds there was always an embryo present, although sometimes not properly differentiated. This suggests that none of the tested substances alone was sufficient to carry the initially swollen fruitlets to maturity unless assisted by some natural hormones associated with the presence of at least one seed.

The growth substances induced a few abnormalities. Persistence of the corolla even on young fruitlets was noticed on branches sprayed with substances Nos. 1, 2 and (2 + 8). Variation in the position of the abscission layer on the pedicel was observed. It occurred sporadically and could not be related to any particular treatment. Some young fruitlets, all of which abscissed later, swelled unevenly, giving the appearance of a young acorn. In some of the mature fruits there was a tendency to abnormal elongation of the calyx end. No leaf abnormalities were found, and the trees made a good extension growth.

Discussion.

This survey of the effect of twenty-six compounds, selected as biologically active and tested upon self- and cross-pollinated apple flowers which had been exposed to low temperatures at varying stages of development, has not led to the discovery of a substance capable of inducing full parthenocarpic development. Nevertheless, initial swelling of fruitlets appeared to be induced by several compounds when applied to self-pollinated Cox's Orange Pippin blossoms, control flowers being abscissed without any swelling. In the case of Ellison's Orange this initial swelling was also common in the controls.

Smith (1950) found that enlargement of the apple fruitlet occurs in two main phases, the first resulting from active cell division and the second from cell expansion. Luckwill (1948) showed that apple seed contained a hormone active in stimulating parthenocarpy in tomato and he suggested that this hormone is associated with the control of fruit abscission. He postulated, however, the existence of a further hormone responsible for controlling the development of the apple fruit. Thus it may be

that more than one growth substance is necessary to initiate the two phases of development and to control abscission.

As a rule, frost damage to styles prevented the initial swelling of flowers in both the apple varieties tested, irrespective of the treatment applied. In self-pollinated Cox's Orange Pippin no swelling occurred beyond the initial stage whatever the treatment applied, even where styles were undamaged. However, some fruits matured from self-pollinated Ellison's Orange flowers and were all found to contain seeds. The fact that these fruits set only after certain treatments and not in the controls suggests the possibility of an effect of such growth promoting substances additional to that of the natural seed hormones. If this is substantiated by further work, it may well prove of value in increasing the normal low set of self-pollinated flowers where conditions for cross-pollination are unfavourable.

All fruits which set from cross-pollinated flowers of Ellison's Orange contained seeds. No clear effect of the application of the growth substances tested could be detected, owing to the complications resulting from the presence of a number of seeds normally capable of bringing a healthy fruit to maturity.

The experiments reported here have shown certain compounds to be effective in delaying abscission and in stimulating the initial stage of development. It is clear that further investigation is required to find more effective substances and to determine their optimum concentration and the most effective time and method of application together with the relationship of their effects to self and cross pollination.

Acknowledgements.

The author wishes to thank Dr. W. S. Rogers for his valuable help in preparing this paper and to Miss N. J. Wallick, Miss S. J. Cogger and Mr. C. H. W. Slater for assistance with the experiments.

She is also indebted to Professor R. L. Wain for kindly selecting and supplying the growth substances synthesized by Mr. C. H. Fawcett, and to Miss D. J. Osborne for advising upon their application.

Summary.

1. The effects were examined of twenty-six organic acids, selected as biologically active, when applied to self-pollinated Cox's Orange Pippin and self- and cross-pollinated Ellison's Orange flowers frozen at various stages of their development.

2. Flowers with frost-damaged styles, whether treated or not, as a rule did not swell. Most of them dropped during the five weeks following freezing and none produced mature fruits.

3. A single application of certain substances delayed abscission while others in addition stimulated the initial fruitlet development of self-pollinated Cox's Orange Pippin.

4. In Ellison's Orange no untreated self-pollinated flowers set fruit, while the full development of treated flowers into mature fruits was always associated with the presence of seeds, suggesting the possibility of an effect of growth-promoting substances additional to that of the natural seed hormones. The initial swelling observed in fruitlets of this variety may have resulted from self pollination.

5. In cross-pollinated Ellison's Orange the seed content obscured the effect of treatments but some indication was found that a combination of certain growth substances was rather more effective than either applied alone.

References

Gardner, F. E. and Marth, P. C. (1937). Parthenocarpic fruits induced by spraying with growth-promoting chemicals. *Science*, **86**, 246-7.

Green, L. (1943). Growth regulators and fruit set with Starking apples. *Proc. Amer. Soc. hort. Sci.*, **42**, 149-50.

Hilton, R. J. (1944). Parthenocarpic fruit production in horticultural plants. *Sci. Agric.*, **24**, 451-5.

Luckwill, L. C. (1948). The hormone content of the seed in relation to endosperm development and fruit drop in the apple. *J. hort. Sci.*, **24**, 32-44.

Osborne, D. J. (1949). Attempts to produce parthenocarpic pears with growth substances. *Ann. appl. Biol.*, **36**, 551-3.

Smith, W. H. (1950). Cell-multiplication and cell-enlargement in the development of the flesh of the apple fruit. *Ann. Bot., Lond., New Series*, **14**, 23-38.

Swarbrick, T. (1947). A review of recent researches on growth-promoting substances in horticulture. *Sci. Hort.*, **5**, 27-39.

THE GRAFTING OF VERY YOUNG APPLE SEEDLINGS

By R. J. GARNER

In apple seedlings the juvenile period or phase normally lasts at least five years ; this is a serious hindrance to breeders of new varieties for it delays the selection of the most promising seedlings. Consequently breeders have given considerable attention to the possibility of hastening fruiting.

Tydeman (1928) worked buds of individual apple seedlings on to the dwarfing rootstocks M.VIII and M.IX and on to the vigorous rootstocks M.X and M.XIII. He found a marked difference in precocity. Fifty per cent of the trees upon the dwarfing rootstocks blossomed in their sixth year whilst less than 9 per cent did so upon the vigorous rootstocks. Moreover, flowering was much more profuse on the trees on the dwarfing rootstocks. Tydeman (1937) also tried pot culture, pruning as against none, grafting scions from two-year seedlings on to mature trees, and, at the same time, repeated his experiment with dwarfing and vigorous rootstocks and showed that of all these methods the use of a dwarfing rootstock was the more effective in inducing early blossoming. Even so, the first blossoms did not appear until five years from germination of the seed and then only on five of the seventeen trees on the dwarfing rootstock. The present study was designed to test methods of grafting seedlings at a very early stage on dwarfing rootstocks with the object of further shortening the juvenile phase.

Material and methods.

The investigation began in the spring of 1950. The seeds available resulted from a Cox's Orange Pippin/Jonathan cross made by Mr. H. M. Tydeman in 1949. The seeds had been sown in boxes in the autumn and began to germinate, under glass, in February, 1950. It was considered desirable to retain the original seedlings and this meant that the first scion available was the epicotyl. A batch of seedlings, at the same stage, were grown from seed obtained from open pollinated M.IX (Jaune de Metz) apple rootstocks in the expectation of obtaining at least some seedling rootstocks of dwarfing habit. Besides these seedlings there were ample supplies of vegetatively raised rootstocks in the form of rooted shoots taken from layer beds, and a limited number lined-out for budding in 1950. In addition a twenty-four-year-old plantation tree of the variety Lane's Prince Albert and two established Worcester Pearmain and Edward VII apple trees in pots were made available for the work. Numerous methods were tried and it is not proposed to describe all the variations, some of which were only used on a very small scale, but to select seven only as possibly of some interest.

Wedge-graft with scion and rootstock in the cotyledon stage.

The rootstock plants were raised from open pollinated M.IX and pricked off into 2 in. pots as soon as the cotyledons separated. The bases of the seedlings used as scions were left in the seed boxes until some three weeks after grafting when they were potted and later hardened off. A safety razor blade proved suitable for making the cuts, though a surgeon's knife (Garner, 1947) was found to be convenient for opening the cleft in the rootstock. The scion was collected by severing immediately above the cotyledons. (It should be emphasized that this was done so that the original seedling was preserved ; the decapitated seedlings soon produced vigorous shoots from buds in the axils of the cotyledons.) The upper part of the first leaf was cut away (Fig. 1) with the object of reducing water loss, the young shoot was laid on a clean wooden surface and a thin slice of tissue was removed from either side, by pressing the razor blade down to the wood, to form a wedge-like base to the scion. The rootstock was now beheaded about $\frac{1}{4}$ in. above the cotyledons and cleft at right angles to them, the cleft extending to cotyledon level. A strip of self-sealing crêpe rubber, as used for surgical purposes, was now placed on either side of the graft and firmly sealed by finger and thumb pressure, taking care to avoid crushing the plant tissues (Fig. 2). The grafted plant in its pot was immediately bedded in peat in a closed case provided with gentle bottom heat. Growth extension was usually seen after a week or ten days and the plants were gently hardened off during the following six to ten weeks when each was planted in the open ground alongside the seedling from which it came.

Wedge-graft with seedling tip and piece-root of M.IX.

Pieces of root were collected from one year transplanted layers of M.IX at the time of grafting and taken into the propagation house and cleft at their proximal end (Fig. 3). The scions were collected from seedlings in the cotyledon stage, as described earlier and were similarly prepared and inserted in line with the cambium within the cleft root. Rubber strip was used for tying and the

grafted roots were curled into small pots which were then filled with peat and placed in a closed case, as described above. Scion growth was excellent, in relation to the total mass of the composite plant, but fresh root growth was slow to begin.

Inlay- and rind-graft with seedling tip and rooted layer.

Well rooted layers of various clonal rootstocks, including M.IX and a new selection of very dwarfing habit, were brought into the propagation house and grafted immediately, or within two weeks of their arrival, meanwhile remaining heeled-in in peat. The first grafts were made with scions still in the young cotyledon stage, but as the work progressed the seedlings used had extended to a height of two inches or so above the cotyledons. The wood of the rootstocks being hard and the seedling tip very soft it was considered that the pressure entailed in tying would tend to crush the delicate scion and an inlay graft was selected for use. The rootstock was shortened to nine inches and its apical end grooved by the removal of a thin wedge about half-an-inch long. The seedling tip, collected from above the cotyledons, received two shallow cuts to form a sideways wedge. These cuts were made with a razor blade pressing down on to a wood surface as already described. The prepared scion was placed

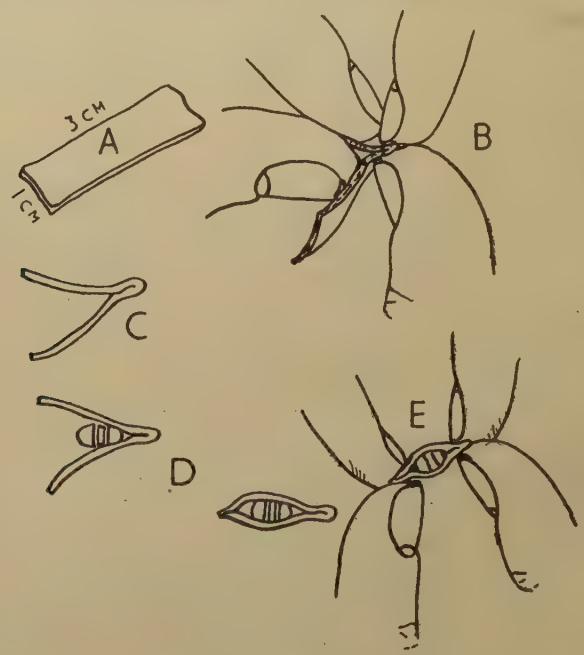


Fig. 2.

Use of crêpe-rubber for cotyledon-stage grafting.

A. Strip of self-sealing crêpe-rubber. B. Folded and nipped along folded edge between thumb and fore-finger. C. Folded strip ready for use. D. Strip placed around the graft and free ends in contact. E. Strip tightened by nipping both sides equally between thumbs and forefingers.

in the groove in the rootstock and held in place by rubber strip. The cut end of the rootstock was lightly smeared with petroleum jelly before bedding the plant in peat in a closed case with bottom heat.

A rind method of grafting (Fig. 4) was also used and was considered better than the inlay method ; it was easier and the newly inserted scions grew away quickly. The rootstocks were shortened to nine inches and the rind was slit down for half-an-inch and lifted on one side only. The scion was prepared by one cut only and this cut surface was placed against the wood beneath the lifted rind, tied with rubber and smeared with petroleum jelly. Later this wound was effectively sealed with the rubber and no petroleum was used.

Inarching a seedling with a rooted layer.

Inarching can be adapted to a wide range of materials and conditions and is less dependent upon accurate manipulation and skilful after care, for the root systems of both components are retained until success is assured. Two methods were used in the inarching of rooted layers ; the inlay and the rind

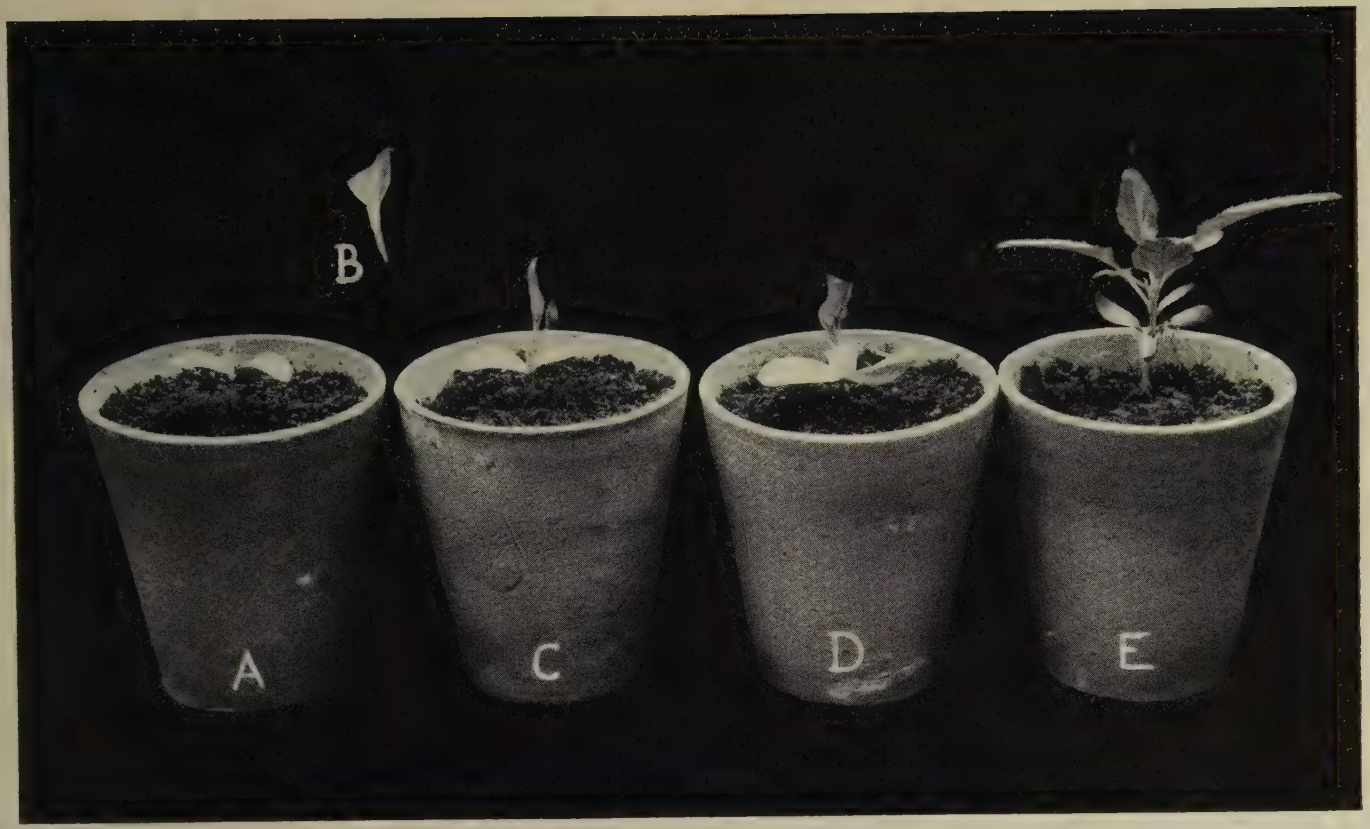


Fig. 1.

Grafting in the cotyledon stage.

A. Rootstock beheaded and cleft. B. Scion with two cuts forming a wedge and leaves trimmed. C. Scion inserted in cleft rootstock. D. Tied and sealed with crêpe-rubber strip. E. A plant six weeks after grafting.

[face p. 72

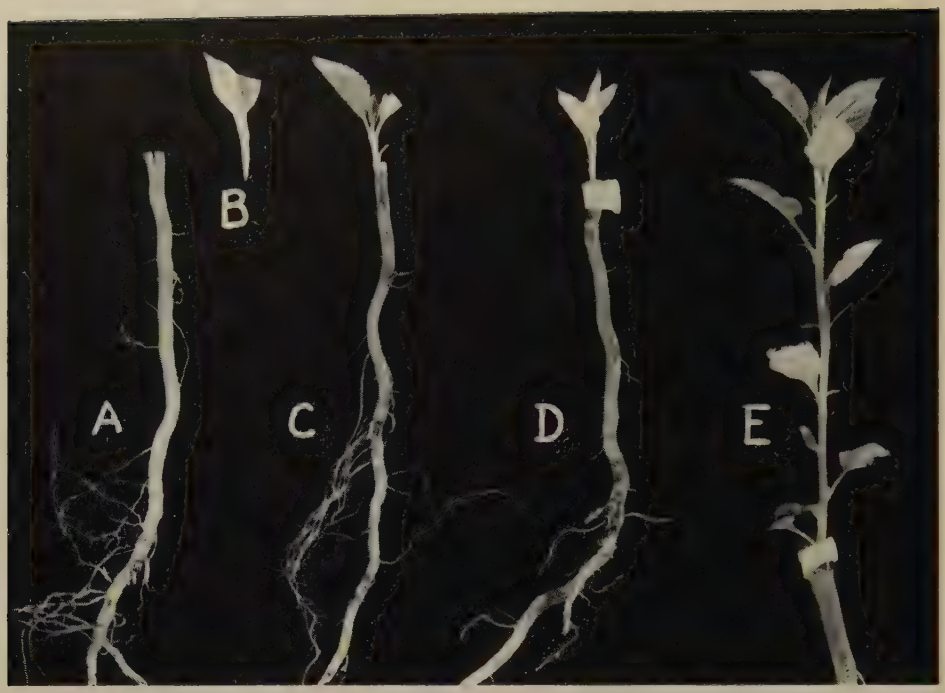


FIG. 3.

Seedling tips inserted into root pieces of M.IX.

A. Root cleft to receive scion. B. Scion with two cuts forming a wedge and leaves trimmed. C. Scion inserted in root. D. Tied and sealed with crêpe-rubber strip. E. A plant six weeks after grafting.

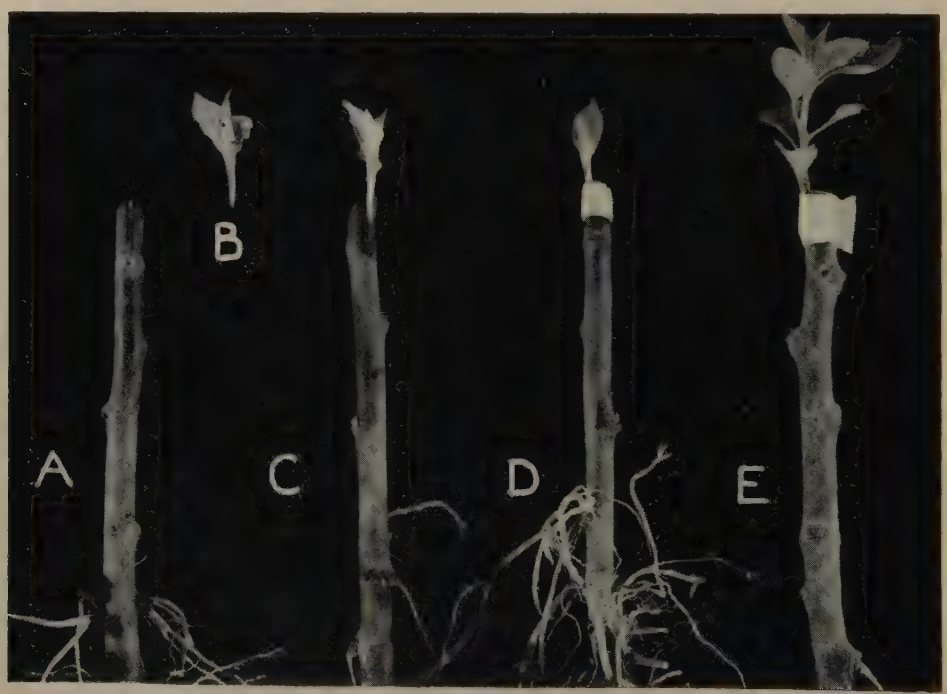


FIG. 4.

Seedling tips rind-grafted into rooted layers of M.IX.

A. Rootstock prepared. B. Scion with one slanting cut. C. Scion inserted in rootstock. D. Tied and sealed with crêpe-rubber strip. E. A plant four weeks after grafting.

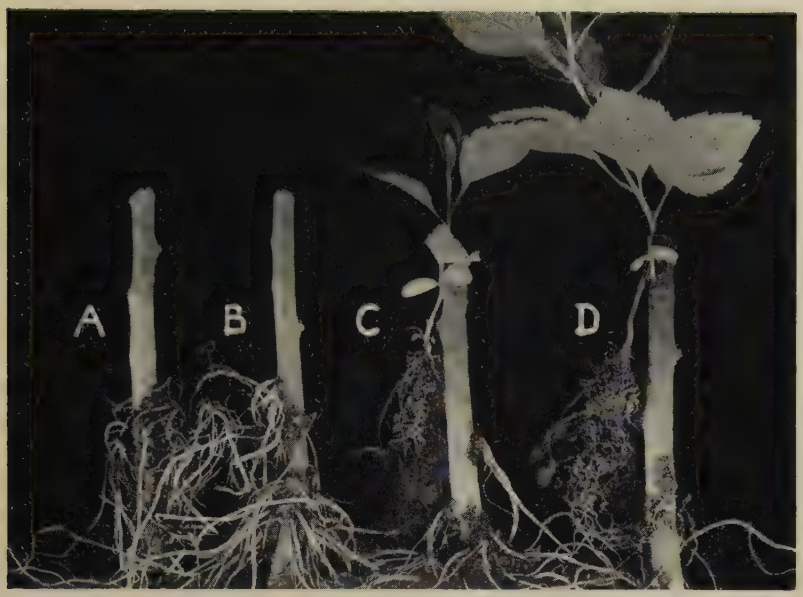


FIG. 5.

Whole seedling inarched with a rooted layer of M.IX.

A. Rootstock prepared for inlay graft. B. Rootstock prepared for rind graft. C. Scion plant inserted and tied with cotton twine. D. A plant four weeks after grafting.

FIG. 6.

Inarching a seedling with a shoot of a mature tree.

Seedling roots enclosed in waterproof bag. Grafted 11th May and photographed 26th June, prior to removal of seedling roots.

A

B

C

FIG. 7.

Approach-grafting a ringed fruiting shoot.

A. A decapitated seedling grafted 9th May and photographed 24th May. B. The same after further growth, photographed 26th June. C. A plant after separation from the fruiting tree showing two fruits of Worcester Pearmain. Grafted 8th May, and photographed 26th June.

(Fig. 5). For inlaying, the rootstock was prepared as described for inlay grafting and the seedling some three inches high received two cuts forming a wedge-like edge about half an inch long. The prepared seedling was fitted into the slot in the rootstock and bound with three or four turns of cotton twine. Exposed cut surfaces were smeared with petroleum jelly and the plants were bedded in peat in a closed case. When the scions had made six to nine inches of growth the seedling roots were partially disturbed and later on completely cut away. This inarching was also done by rind-grafting (Fig. 5). The rind of the layer was slit down for half-an-inch and then for a quarter-of-an-inch around to form an L shaped incision. The seedling was sliced on one side only and fitted beneath the rind flap on the layer, tied and smeared with petroleum jelly.

Inarching a seedling with a shoot of a mature tree.

On 11th May, when the seedlings were from three to six inches high, fifty were set aside for inarching with shoots of a mature fruiting tree of the variety Lane's Prince Albert. The top of each seedling was taken and struck as a soft-wood cutting. The decapitated seedlings were then knocked out of their pots, wrapped in waterproof cloth, tied to a lateral shoot of the tree (Fig. 6) and grafted as described for inarching rooted layers into young seedlings by the rind method. Adhesive cloth tape was used for tying and this was later reinforced with raffia. Exposed cut surfaces were sealed with petroleum jelly. Frequent watering was necessary in dry weather ; twice in three days in dry periods.

Grafting a seedling by approach above a ring on a fruiting shoot.

It has been noted (Sen, 1945) that in the propagation of mango by approach grafting young seedling rootstocks to selected mature trees the seedling has flowered, but only where the mature shoot was ringed below the graft. In order to test this technique on the apple, fourteen seedlings, some seven inches high, and two fruiting trees, one Worcester Pearmain and one Edward VII, were used. Tip cuttings of each seedling were struck in a propagating case and then the seedlings, in their pots, were approach-grafted to flowering shoots, seven on each of the trees, immediately above a quarter inch wide ring from which the rind was completely removed (Figs. 7 and 8). This was done on 9th May and by 23rd June the first three seedlings were freed from the trees by cutting through the mature shoot at the ring. Shoots which had extended from the seedling, above the graft (Fig. 7b) were removed and treated as cuttings. By 25th August all the seedlings, with the mature scions, had been removed from the tree and planted in open ground under partial shade, along with the rooted counterparts. One of the plants taken from the tree on 23rd June was bearing two fruits of Worcester Pearmain which attained a diameter of $1\frac{1}{4}$ inch and abscissed at the end of August having developed the characteristic flavour of the variety. Buds will be allowed to develop on the rootstock stem and flower production in this area will be compared with that of the rooted cuttings.

Seedling bridges on ringed rootstocks and branches.

It was considered possible that an early effect, of either a rootstock or a mature tree, might be obtained if the materials carried in the rind were passed through the seedling whilst it was still only a few months old. The girdling of the rootstock stem or tree branch and its bridging with a piece of seedling stem should suffice. The stems of twenty-five seedlings were collected and one bud from each was budded into the rootstock M.IX in the nursery row and one into two-year lateral shoots of the mature tree of Lane's Prince Albert previously mentioned. Each seedling stem was then cut in halves and one piece used for bridging a ringed M.IX, similar to those which had been budded, and the other piece served to bridge a girdled two-year shoot on the mature tree. The wounds to be bridged were formed by removing $\frac{3}{4}$ inch wide rings of rind. These wounds were left exposed for three hours or more and then bridged in the normal way and all exposed cut surfaces were smeared with petroleum jelly. The operation was done at the end of August and by the end of October examination revealed that all the bridges on the M.IX rootstocks were successful, whereas a number of the ringed shoots on the mature tree had been broken, presumably by strong winds. It was also seen that the foliage above the rings, in both situations, had developed a purple tinge, whereas the leaves on the budded rootstocks and shoots were still green. Many of the stripped areas around the rootstocks had developed a new rind which had clearly arisen directly from the surface beneath the smear of petroleum jelly. This was not visible in the rings on the mature tree.

General considerations.

The seven methods described are only a few of the many techniques available, or awaiting development, and it yet remains to be proved that any one will be more useful than another in helping to

hasten the onset of flowering, which is the final objective of these investigations. In the meantime it is possible to assess the comparative efficiency of the methods in relation to ease of manipulation and proportion of successful unions.

Of all methods of grafting, the popular method known as budding or shield-budding, is probably the simplest and normally shows a high degree of success, though it entails at least a year's delay in the production of a tree whilst the scion-bud develops on the seedling and then lies dormant in the root-stock till the following spring. Methods of grafting described in this paper are designed either to obtain a tree on a clonal rootstock, known to aid early fruiting, of the same age as the unworked seedling, or to place the seedling under " maturing " influences during its first season of growth. Where very many individual seedlings are to be worked it is important to use a simple technique, provided it is

FIG. 8.

Seedling approach-grafted to a ringed fruiting shoot.

A. Fruiting shoot ringed. B. Seedling in pot, fixed firm and level for watering. C. Ringed shoot and seedling prepared by slicing. D. Graft completed by sealing with adhesive cloth tape.

efficient. Of the methods described the rind-grafting of a seedling tip to a rooted layer appears to be the most suitable and efficient. In this method there were practically no losses, due to failure to form a union, but there was a considerable number of deaths due to rotting of the rootstock which spread from the base. It was found that this rotting was almost entirely absent when the rootstocks were established in pots a few weeks before grafting, and it appears likely that potting rootstocks whilst dormant, and starting in gentle heat, will give the best results. In one batch of rootstocks set in pots a few weeks prior to grafting, 95 per cent were successfully worked, hardened off and lined out in the nursery.

The success with which succulent non-lignified scions are grafted to woody rootstocks amply demonstrates that it is not at all essential for the scion to be less advanced in growth than the stock,

at least in the controlled environment within a propagating case. The use of glasshouse and ancillary equipment involves considerable expense and should seedling-stage grafting be widely used some simpler method for use in the open nursery will doubtless be welcome. It is hoped that it will prove possible to devise an efficient method to satisfy that need.

Acknowledgements.

Mr. H. M. Tydeman provided all the seedling material. Mr. E. G. Coker and Miss C. P. Nicoll helped with the grafting. This assistance is gratefully acknowledged.

Summary.

The need for hastening the onset of fruiting of seedling apples is noted. Earlier evidence that the use of " dwarfing " rootstocks encourages early fruiting suggests that grafting seedlings at a very early age to selected stocks may intensify this effect. Seven methods of grafting apples in the cotyledon and early seedling stage on to mature trees, clonal rootstocks and young seedlings are described. No difficulty was encountered in successfully uniting scions in the cotyledon stage with one year clonal rootstocks established in pots under glass, and it is hoped to develop this technique for use in the open nursery.

References.

Garner, R. J. (1947). The grafter's handbook. Faber, London, p. 70.

Sen, P. K. (1945). On the flowering on stock stem of mango grafts at nursery stage. *Indian J. Hort.*, **3**, 92-5.

Tydeman, H. M. (1928). The influence of rootstocks on the blossoming of seedling apples. *Rep. E. Malling Res. Sta. for 1927, II Suppl.*, 51-5.

——— (1937). Experiments on hastening the fruiting of seedling apples. *Rep. E. Malling Res. Sta. for 1936*, 92-9.

THE USE OF GROWTH SUBSTANCES TO WIDEN CROTCH ANGLES

By A. P. PRESTON and H. W. B. BARLOW*

Introduction.

Heavy cropping in plum trees may result in breakage of main branches near the crotch causing the loss of a large part of the trees' cropping capacity (Fig. 1). The most general cause of this breakage appears to be the insertion of the primary branches at a narrow angle to the trunk. To meet this problem the use of a growth substance to secure wide angles when forming the primary branch framework has been investigated.

Work by Verner (1939) on apple tree building has shown that by allowing indole-3-butyric acid to diffuse slowly over a long period into the cut at the head of a cut-back maiden tree while dormant, abnormally wide crotch angles were developed over the entire tree. The uppermost branches, which normally develop the narrowest angles, were most affected ; the average crotch angles for the first three branches was 59° for treated trees and 35° for untreated ones. The concentration of indole-3-butyric acid used varied from 5 to 25 mg. per 100 gm. of lanolin but, while in general there appeared to be a positive correlation between concentration of the growth substance and degree of epinastic effect on the shoots, no recommendations for an optimum concentration were made.

The present writers have made preliminary investigations during 1949 and 1950, of the effect of applying various concentrations of indole-3-butyric acid in lanolin to the cut surfaces of headed-back maiden and two-year-old plum trees of the variety Victoria, in an attempt to secure wide crotch angles on the primary branch framework.

Material and methods.

The trial in 1949 consisted of 20 maiden (one-year-old) trees of Victoria on Common Plum planted 14 ft. apart in a single row. The treatments applied were :

A—lanolin paste alone.
B—10 mg. indole-3-butyric acid per 100 gm. lanolin paste.
C—30 mg. indole-3-butyric acid per 100 gm. lanolin paste.

The design consisted of single tree plots within three randomized blocks, there being two plots of each treatment within each block. The trees were headed back to approximately 153 cm. above the union on 24th March and care was taken to ensure that the cut was made just below a bud so that a piece of internodal wood, approximately 5 cm. in length, was left above the first bud ; this served to accommodate a rubber tube 7 cm. long which was slipped over the cut and overlapped the internode by 2 cm. (Fig. 2). The lanolin paste was slightly warmed to liquefy it and applied down the tube which was then corked. The first six shoots were allowed to grow out while other shoots were rubbed out completely.

In 1950 the same trees used the previous year were headed back to approximately 100 cm. from the union and used for a further trial as cut-back two-year trees. In addition twenty maiden trees of the same variety on the same rootstock were interplanted along the row and were headed back to 153 cm. as already described. The following treatments were applied to the two sets of trees :

A—lanolin emulsion alone.†
B—10 mg. indole-3-butyric acid per 100 gm. lanolin emulsion.
C—30 mg. indole-3-butyric acid per 100 gm. lanolin emulsion.
D—90 mg. indole-3-butyric acid per 100 gm. lanolin emulsion.

The randomization of treatment was done separately for maiden and two-year-old trees.

As the rubber tubes had proved unsatisfactory for outdoor conditions the previous year, a strip of transparent celluloid 8 × 6 cm. and 12/1,000 inch thickness was cut for each tree, wrapped around the topmost internode and secured with an elastic band. Five cc. of the emulsion was placed into each tube, and a thin test tube 5 × 1·5 cm. was slipped over its mouth (Fig. 2). This method proved very satisfactory and also allows one to see whether the emulsion is in contact with the tree.

As in 1949, the first six shoots from the cut were allowed to grow out, other shoots (feathers) were shortened back to 10 cm. during the summer.

* Member of staff of the Research Institute of Plant Physiology, Imperial College of Science and Technology.
† Prepared according to Winklepleck and McClintock (1941).

Experimental results.

As the 1949 growing season advanced it soon became evident that there were no visible differences in crotch angle between the control treatment A, and treatments B and C. It is interesting to note that treatment C, 30 mg. indole-3-butyric per 100 gm. lanolin paste, was higher than the highest concentration used by Verner.

The trial in 1950 on the two types of tree included two of the previous year's treatments but lanolin paste was replaced by lanolin emulsion. Measurements of crotch angles and of branch lengths of each of the six primary branches were made.

Crotch angles.

Mean values for the crotch angles of the first three primary branches are shown for two-year-old and maiden trees in Table I. In the case of the two-year-old trees the differences between treatments

TABLE I.

MEAN CROTCH ANGLES (DEGREES FROM VERTICAL), 1950. BRANCHES 1, 2 AND 3.

Treatment.	Cut back 2 year trees. Branch number.			Cut back maiden trees. Branch number.		
	1	2	3	1	2	3
A	23	31	26	28	32	47
B	33	28	26	33	33	46
C	28	25	41	40	44	45
D	42*	24*	34†	51	49	53

Figures bracketed together do not differ significantly. * differ significantly from each other, but not from †.

and between branches were not significant, but there was a significant interaction between them. The trees were very severely cut back before the 1950 treatments were applied so that it is not surprising that the vigorous branches resulting from such drastic treatment should have relatively narrow angle crotches.

In the case of the maiden trees, however, both the main effects of treatment and of branches, as well as their interaction, were significant. Here there is a difference of 23° for the first branch crotch angle between the control and treatment D, with differences of 17° for the second branch and 6° for the third. Averaging the data for the three branches, treatment D gave significantly greater angles than any of the others, the mean angle being 51°, while the remaining treatments did not differ significantly.

TABLE II.

MEAN CROTCH ANGLES (DEGREES FROM VERTICAL), 1950. BRANCHES 4, 5 AND 6—CUT BACK MAIDEN TREES.

Treatment.			
A	B	C	D
73	63	57	57

Branch number.		
4	5	6
54	61	74

Figures bracketed together do not differ significantly.

There were no significant effects of either treatments or of branches on the mean crotch angles for branches 4, 5 and 6 on the two-year-old trees, but on the maiden trees treatment A resulted in significantly wider angles than did treatments C and D. There were also significant differences between these branches on the maidens, as shown in Table II, but there was no interaction of treatments with branches.

Branch length.

The application of growth substance has resulted in depressing the growth of the first three branches; Table III shows significant differences between treatments on the maiden trees and while the differences between the first three branches on the two-year-old trees fail to reach significance, there is a clear indication that the higher concentrations of growth substance depressed the growth on these trees also. There were no significant differences between treatments for length of branches 4, 5 or 6 on either the maiden or the two-year-old trees.

TABLE III.

MEAN TOTAL LENGTH OF BRANCHES, JULY, 1950—CUT BACK MAIDEN TREES.

Treatment.	A	B	C	D
Total for branches 1, 2 and 3 (cm.)	179·2	165·0	96·0	74·7

Figures bracketed together do not differ significantly.

Discussion.

Although it is clear that the growth substance, at least at the higher concentrations, has depressed the growth of the first three branches (Table III), nevertheless they remained quite suitable in size. Indeed, in selecting primary branches it is advisable to select three or four well-spaced branches of different length and thickness as a further insurance against branch breakage in later years, for it is with branches of more or less equal girth in addition to narrow crotch angles that branch breakage is most severe. This has been the case with Laxton's Delicious plum at East Malling where 8 out of 12 trees have lost most of their primary branches and 6 of them have had to be grubbed already before reaching 12 years of age. This was certainly not due to heavy cropping and it seems likely that in this case the crotches were insufficiently strong to bear the weight of the branch system (see Fig. 1).

Treatment D, the strongest concentration of indole-3-butyric acid used, resulted in good crotch angles in the primary branch framework and is a treatment which may prove to be of practical importance in building plum trees less liable to break their framework under heavy crops. It would seem advisable to remove the tube from the tree by the end of July at the latest, so that the internode can be cut back with the least risk of infection by the Silver Leaf fungus.

It is interesting to note that branches 4 to 6 gave wide crotch angles without the use of the growth substance, in fact wider without than with them. It therefore seems that one method of avoiding narrow crotch angles in the primary framework would be to cut the maiden tree 10 or 15 cm. higher than is needed, allowing six primary branches to form the first year and heading back the tree to the fourth branch in the second winter, thus leaving branches 4, 5 and 6 as wide angled primary branches. This treatment appears practicable where the variety habitually breaks all its buds after planting, as Victoria does, except under drought conditions. During 1949, a severe drought year at East Malling, the growth of branches 5 and 6 on many trees was insufficient to warrant their being considered as possible primary branches.

Observations by growers and nurserymen suggest that in general Pershore Yellow is most shy in breaking buds, followed by Burbank's Giant Prune, especially on heavy land. Cambridge Gage, Early Laxton, Marjorie's Seedling, Warwickshire Drooper and Oullin's Golden Gage are also reported to be shy or uneven in breaking. For such varieties the use of growth substances may prove to be especially valuable. Further tests, both of initial pruning methods and of growth substances at even higher concentrations, would be desirable.

Fig. 1.

Severe breakage of primary branches on Delicious plum.

[face p. 78

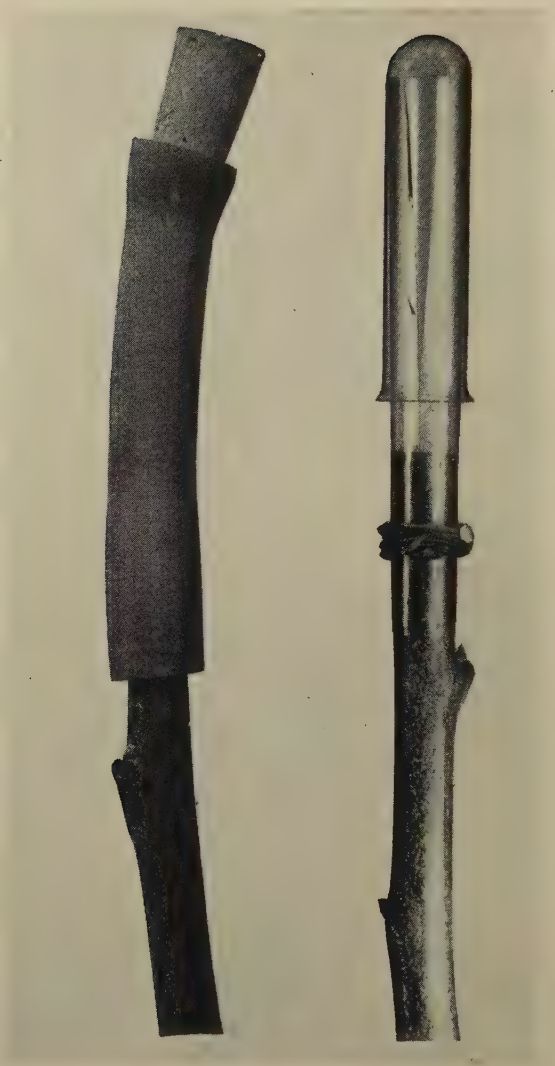


FIG. 2.

Two methods of applying growth substance in lanolin paste or emulsion to cut back tree ; (left) rubber tube with cork, (right) transparent celluloid strip coiled round stem and fixed with rubber band and test tube cover in place. Note internode above first bud to hold tubes.

Acknowledgements.

The writers wish to thank Mr. J. Taylor of the Statistical Section for assistance in planning the experiments and carrying out the analyses. Also Mr. R. P. Longley, a visiting worker from the Dominion Experimental Farm, Kentville, Canada, who assisted in collecting the data during 1950. Many growers, nurserymen and N.A.A.S. Officers co-operated in answering a questionnaire on varietal differences in bud break with plum trees.

Summary.

1. The importance of obtaining wide angled primary branches with plum trees is stressed in relation to subsequent branch breakage.

2. An experiment is described where different concentrations of indole-3-butyric acid were applied to cut back maiden and two-year-old trees to encourage wide angled crotches in the primary branch framework. Details of the technique of applying the growth substance to the tree are given.

3. Indole-3-butyric acid, applied as a lanolin emulsion containing 90 mg. per 100 gm. showed an improvement of 23° for the first branch crotch angle over the control treatment without growth substance.

4. The higher concentrations of growth substance depressed the growth of the first three primary branches.

5. The results from this trial are discussed in relation to their practical importance in nursery and orchard work.

References

Verner, L. (1939). The effect of a plant growth substance on crotch angles in young apple trees. *Proc. Amer. Soc. hort. Sci.*, **36**, 415-22.

Winklepleck, R. L. and McClintock, J. A. (1941). Lanolin emulsions as carriers of growth substances. *Proc. Amer. Soc. hort. Sci.*, **38**, 94-6.

WALNUT VARIETIES

By ELIZABETH M. GLENN

Several descriptions of the more important American and continental varieties of walnuts have been published (e.g. Batchelor, 1929 ; Roy, 1938), and preliminary descriptions of some of the English varieties (Hamond, 1936 ; Witt, 1938 ; Glenn and Witt, 1946 ; Glenn, 1947), but there are no full descriptions of the English varieties.

The walnuts described in the present paper are grown for their nuts and do not include any selected primarily for their timber. The most important and most easily recognizable differences between these varieties are in the time of leafing out in spring and in the quality and appearance of the nuts. The time of leafing out is of great importance in this country as the young shoots are very susceptible to damage by spring frosts. Varietal differences also occur in tree size and shape and in the leaves and flowers.

VARIETAL CHARACTERS.

Tree size and shape.

In the field trials at East Malling, Leeds Castle has proved to be the most vigorous of the selected English varieties, although one or two others approach it in vigour. Champion of Ixworth has made the weakest growth. Fig. 1 shows the relative sizes of three varieties on *Juglans nigra* rootstock. The mean height and spread of these varieties at nineteen years old was as follows : Leeds Castle 22 × 26½ ft., Northdown Clawnut 18 × 18½ ft., and Champion of Ixworth 15½ × 14 ft.

The typical shape of a mature walnut tree is rounded and spreading, but young trees vary from very spreading, e.g. Franquette, to upright and narrow, e.g. Stutton Seedling (see Fig. 2).

Leafing out.

In Southern England the earliest varieties leaf out at the end of March or the beginning of April, and are often killed back by frost. The latest varieties leaf out in the first or second week of May, and so usually escape frost injury to the shoots, although their pollen catkins may occasionally be damaged by a late frost.

Leaves.

The leaves are pinnately compound, with a terminal leaflet and usually three or four pairs of almost sessile lateral leaflets. The leaflets are practically glabrous, except for small clusters of yellow, glandular hairs on the under surface, in the angle between the main veins and midrib.

The leaves vary in size, shape and colour, and in the number of leaflets. The leaflets vary from oblong to oval and from broad to narrow, and they may be flat, or have the margins rolled up (see Fig. 5).

The angle between the midrib and main veins of the leaflets varies from an acute angle to almost a right angle.

The young leaves and shoots are usually reddish in colour when they first develop in the spring. This red colour disappears as the leaves reach full size. The amount of red colouring is characteristic of the variety, most of the late leafing varieties having very red leaves and shoots in spring, and some other varieties, e.g. Persian, being almost pure green from the beginning.

Flowers.

The pollen catkins are clearly visible on the trees in winter, appearing as small, conical buds, without leaf scales. The catkins vary in shape from short and round, to narrow and pointed (see Fig. 3). When mature and shedding pollen in the spring, the catkins usually curve downwards, and vary in shape from short and fairly broad, to long and narrow (see Fig. 5).

In most varieties the pistillate flowers are borne in groups of two or three, but in some varieties, e.g. Fertilis (East Malling Research Station Index No. P20), and Patching, they are borne in large clusters, the basal flowers developing first. The terminal flowers of a large cluster usually fail to develop.

Walnuts are dichogamous, the catkins and pistillate flowers developing at different times. Most varieties are protandrous, the catkins beginning to shed pollen before the pistillate flowers are receptive.

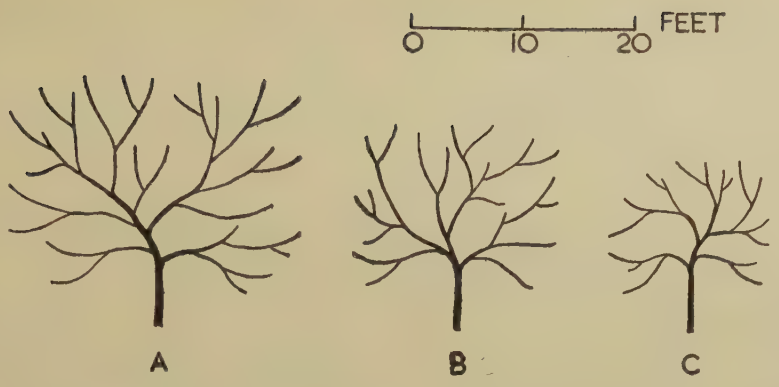


FIG. 1.

Relative size of tree at nineteen years old. A. Leeds Castle. B. Northdown Clawnut. C. Champion of Ixworth.

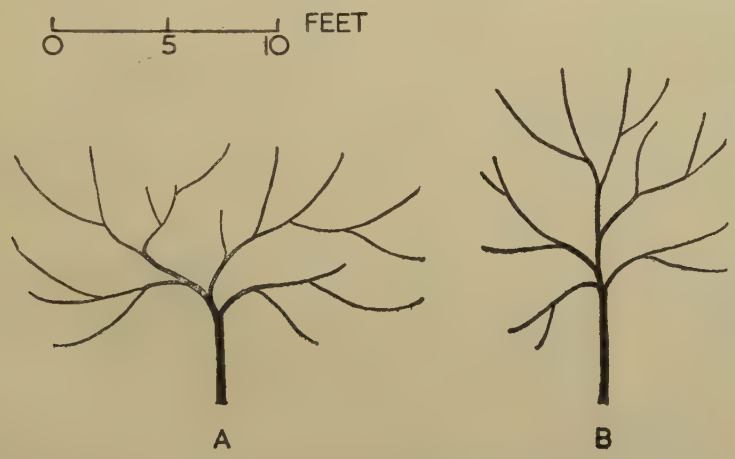


FIG. 2.

Differences in shape of tree at twelve years old. A. Franquette. B. Stutton Seedling.

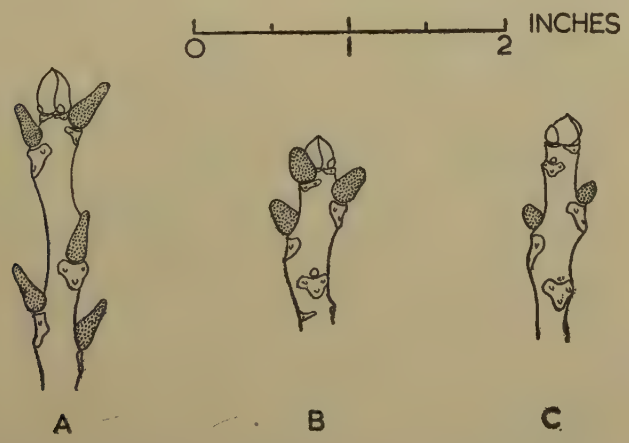


FIG. 3.

Dormant catkins. A. Long and narrow, as in Leeds Castle. B. Broad, with blunt tip, as in Franquette. C. Very small, as in Persian.

In young trees the catkins have often shed all their pollen before the first pistillate flowers are ready, and so the latter are not fertilized unless there is another tree nearby with ripe catkins at the right time. In older trees the amount of dichogamy is less, and some of the catkins and pistillate flowers mature together.

In protogynous varieties, where the first pistillate flowers are receptive before the catkins begin shedding pollen, there is usually a good chance of self pollination, even in young trees, because the pistillate flowers are not all over before the catkins shed any pollen.

Nuts.

The nuts vary in size from over 2 × 2 in., down to $\frac{3}{4} \times \frac{3}{4}$ in., or even smaller (Figs. 4 and 6). The argest nuts are not necessarily the best, because they are often only poorly filled.

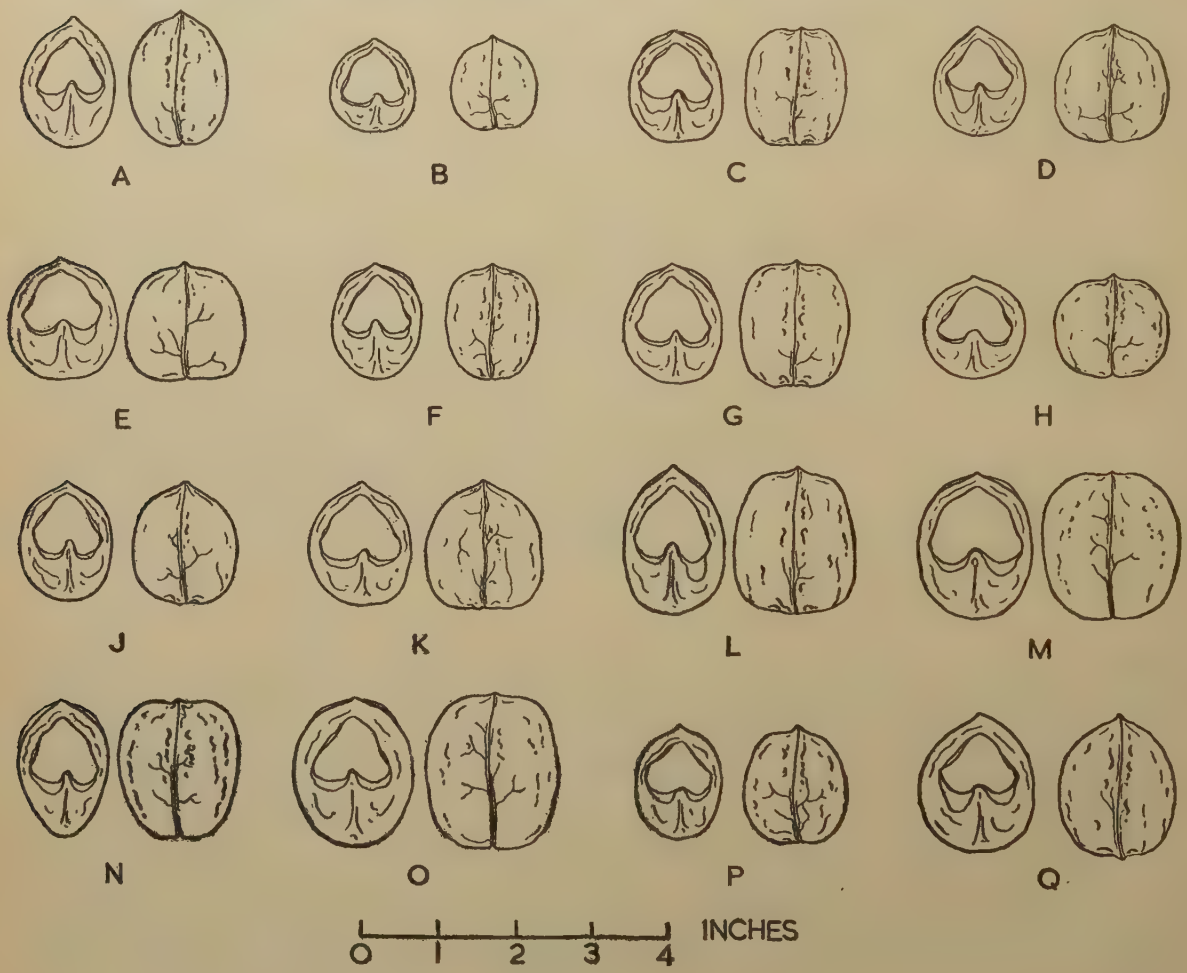


FIG. 4.

Nuts. A. Franquette, P128. B. Fertilis, P20. C. Mayette, P11. D. Leib Mayette, P103. E. Newgates Mayette, P88/1. F. Parisienne, P9. G. Treyve, P13. H. Persian, P100. J. Champion of Ixworth, P172. K. Excelsior of Taynton, P167. L. Lady Irene, P169. M. Northdown Clawnut, P170. N. Secrett, P150. O. Stutton Seedling, P171. P. Leeds Castle, P168. Q. Patching, P149.

The shell thickness varies greatly. The thick shelled nut is usually well sealed, but it may be difficult to extract the kernel without breaking it. The thinner shells are sometimes imperfectly formed, especially in wet years.

The surface of the shell may be fairly smooth, as in Northdown Clawnut, giving an attractive appearance to the nut, or the surface may be deeply ridged and pitted, making it difficult to clean when harvesting the nuts.

FIG. 5.

A. Leaflets rolled up at the margins, as in Leib Mayette. B. Leaflets more or less flat, as in Persian. C. Catkins long and hanging down, as in Leeds Castle. D. Catkins short and held out, as in Leib Mayette.

[face p. 82

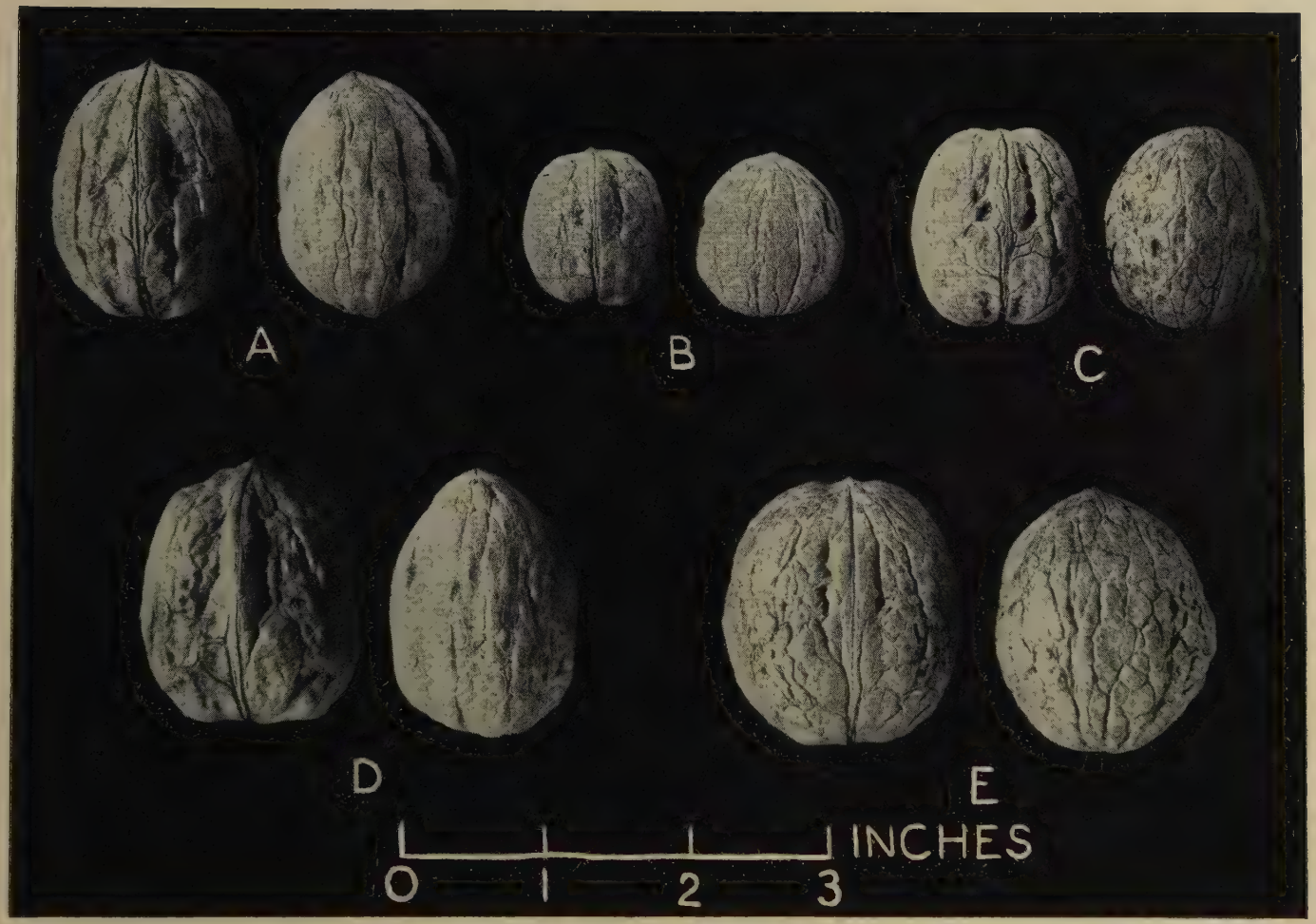


FIG. 6.

A. Franquette, P128. B. Fertilis, P20. C. Mayette, P11. D. Lady Irene, P169. E. Northdown Clawnut, P170.

There are varietal differences in shell colour, although this is affected to some extent by the method of harvesting and cleaning the nuts.

The green husk enclosing the nut varies from very thick, as in Lady Irene, to thin, as in Excelsior of Taynton. Thus, before husking, the nuts of the former variety appear twice as large as those of the latter, although the husked nuts are about the same size.

The green husks of Northdown Clawnut are always somewhat russeted. Russeting occurs occasionally in other varieties, but not normally to the same extent as in Northdown Clawnut.

In a few varieties, e.g. Fertilis (P20), the green husks are covered with short hairs up to the time the nuts are ripe. In most varieties the husks are only hairy when the nuts are small, and they are more or less glabrous by the time the nuts are full size.

The nuts may be borne singly, in pairs, or in large clusters.

DESCRIPTIONS OF SOME IMPORTANT VARIETIES.

Continental and American varieties.

Fertilis (P20).

Juglans regia fertilis or *praeparturiens* is usually recognized as a sub-species of *J. regia*. It is said to form a small tree, or bush, bearing clusters of nuts, and cropping at an early age. The clonal selection P20 appears to have many of the characteristics of this sub-species.

Tree. Small and compact, with a fairly dense round head. Leafs out in early April, too early to escape spring frosts except in comparatively frost free situations. The young shoots are very red in spring.

Leaves. Light green, medium to large, with a short rachis. The leaflets are oblong, flat, with a fairly large terminal leaflet, and often only two pairs of lateral leaflets. The tufts of glandular hairs on the under surface are conspicuous.

Flowers. Protandrous. The dormant catkins are of medium size, broad and pointed. When shedding pollen they are of medium size and broad. This variety bears numerous catkins, but the majority are often killed by frost. The pistillate flowers are very numerous, borne in clusters.

Nuts. Small, round, or slightly conical. Shell thin, well sealed, well formed even in wet seasons, pale in colour, smooth, of attractive appearance in spite of its small size. Nuts very well filled, flavour very good. Good for pickling or dessert. Nuts borne in clusters. The green husk is downy or hairy, even when the nut is ripe. A heavy cropper, except when killed back by spring frosts.

Franquette (P128).

This appears to be the true Franquette of France and America, and under our conditions is the best of the French varieties.

Tree. Vigorous, very spreading, leafing out late. The young shoots are very red in spring.

Leaves. Medium green, medium sized. The leaflets are oval, slightly rolled up at the margins. The rachis is slender.

Flowers. Protandrous. The dormant catkins are broad and of medium size. When shedding pollen they are fairly short and broad, and are held out nearly horizontally, rather than hanging straight down. The pistillate flowers are borne in pairs.

Nuts. Medium sized, long oval, pointed. Medium thick shell, well sealed, well filled. Shell light in colour, fairly smooth, with a prominent sutural ridge, attractive appearance. Flavour excellent, both when fresh and when dried.

Leib Mayette (P103).

A good American strain of Mayette, close to the true French Mayette in appearance.

Tree. Medium sized, spreading, with a rather thin, open head. Leafs out late. The young shoots show a fair amount of red colouring in spring.

Leaves. Fairly small, medium dark green. Leaflets oval, narrow, with rolled up margins. Rachis slender.

Flowers. Protandrous. The dormant catkins are broad and of medium size ; when shedding pollen they are of medium size, and held nearly horizontally. Pistillate flowers borne in pairs.

Nuts. Medium sized, round or conical, pointed, with a flattened base. Shell fairly thin, sometimes imperfectly formed in wet seasons, well sealed when perfect, smooth, bright colour and of attractive appearance. Nuts well filled, flavour good.

Mayette (P11).

There are many strains of this variety, and this is probably not the true French Mayette.

Tree. Vigorous, fairly spreading, leafing out late. The young shoots in spring are very red.

Leaves. Medium to large, dark or medium dark green. Lateral leaflets oval-obovate, rolled up at the margins, terminal leaflet large, with a blunt tip, tapering to base, flat or slightly rolled at the margins.

Flowers. Protandrous. The dormant catkins are of medium size and blunt tipped ; when shedding pollen they are of medium size, and held nearly horizontally. This variety does not bear catkins freely, at least when young. Pistillate flowers borne in pairs.

Nuts. Medium sized, fairly long with parallel sides and a blunt apex. Shell medium thin, sometimes rather dark in colour, smooth, well sealed. Nuts well filled, flavour very good. A good quality nut, but only a moderate cropper.

Newgates Mayette (P88/1).

This variety has most of the characters of a Mayette, except that its flowers are protogynous.

Tree. Fairly vigorous, not very spreading, pyramidal in shape. Leafs out late. The young shoots in spring are very red.

Leaves. Large, dark green. The leaflets are oval, hanging down, with rolled up margins. The veins are conspicuous, light green against the dark interveinal parts of the leaf. The rachis is usually hairy.

Flowers. Protogynous, unlike other strains of Mayette. Being late leafing as well as protogynous, the catkins are very late, and escape damage by even exceptionally late frosts. Bears numerous catkins. The dormant catkins are small, oblong, with blunt tips. When shedding pollen they are long. Pistillate flowers borne in pairs or in threes.

Nuts. Medium sized, broad, round or slightly conical, with a flattened base. Shell thin, very smooth, well sealed, well filled. Flavour very good. Good and regular cropper, and because of the late catkins, it can act as a good pollinator to other varieties.

Parisienne (P9).

This is another variety from France.

Tree. Spreading, not very vigorous, leafing out late. The young shoots are more hairy than in most other varieties, with a medium amount of red colouring in spring.

Leaves. Small, dark green. There are usually four pairs of lateral leaflets. The leaflets are ovate, pointed, with rolled up margins. The terminal leaflet is small and pointed. The rachis is usually hairy.

Flowers. Protandrous. The dormant catkins are of medium size, oblong, with blunt tips. When shedding pollen they are short and broad. Pistillate flowers borne in pairs.

Nuts. Medium sized, with parallel sides and a blunt apex, very similar in appearance to Mayette (P11). Shell fairly thick, rather dull in colour, well sealed, fairly well filled. Flavour good.

Persian (P100).

This variety was obtained from Canada.

Tree. Vigorous, spreading, making a large tree with a dense, round head. Leafs out at mid-season. The young shoots in spring are almost pure green, with very little or no red colouring.

Leaves. Large, dark green. The leaflets are very characteristic, being broad and short, and flat or even down cupped. The terminal leaflet is often circular. The rachis is short, and the glandular hairs on the backs of the leaflets are few.

Flowers. Protogynous. Bears only few flowers when young. The dormant catkins are very small and round. When shedding pollen they are medium to small and short. Pistillate flowers borne in pairs or in threes.

Nuts. Medium to small sized, round, broad. Shell fairly thick, with well-marked sutural ridge, pale in colour, well sealed, well filled. Flavour good when fresh, rather sweet, tends to loose its flavour on drying. Early ripening. Late in coming into cropping.

Treyve (P13).

Very similar to a Mayette in many of its characters.

Tree. Medium vigour, fairly spreading, leafing out late. The young shoots are very red in spring.

Leaves. Medium sized, dark green. The leaflets are oblong, with rolled up, often wavy, margins, not quite sessile. The terminal leaflet is small in relation to the lateral leaflets. The rachis is slender.

Flowers. Protandrous. The dormant catkins are of medium size, blunt. When shedding pollen they are medium in length and breadth. Pistillate flowers borne in pairs or in threes.

Nuts. Medium sized, with parallel sides and a blunt apex, rather similar to Mayette (P11). Shell fairly thick, bright coloured, fairly well filled. Flavour good.

English varieties.

Champion of Ixworth (P172).

The original tree of this variety is at Ixworth, Suffolk.

Tree. Small, weak growth, leafing out at mid-season. The young shoots show a medium amount of red colouring in spring.

Leaves. Small or medium small, dark blue-green with paler spots. Leaflets oblong, rolled up at the margins, terminal leaflet broad. Glandular hairs prominent on the backs of the leaflets.

Flowers. The trees at East Malling, up to nineteen years old, have only borne occasional catkins, and only a medium number of pistillate flowers. The flowering shoots are longer and form more leaves before the pistillate flowers appear, than is common in most walnut varieties. Pistillate flowers borne in pairs.

Nuts. Medium sized, oval, pointed. Shell often imperfect and poorly sealed. Nut well filled, flavour very good. This variety has only borne very light crops at East Malling.

Excelsior of Taynton (P167).

The original tree is at Huntley, Gloucestershire.

Tree. Very vigorous, especially in the nursery. Makes a large tree, with a silver-grey trunk. Leafs out at mid-season. The young shoots are very red in spring.

Leaves. Medium sized, medium to dark green. Lateral leaflets long, oval-ovate, rolled up at the margins. Terminal leaflet broad. Rachis long.

Flowers. Protogynous. The dormant catkins are very small, narrow and pointed. When shedding pollen they are long and hang straight down. Pistillate flowers borne in pairs.

Nuts. Large, oblong or conical in shape, pointed. Shell thin, sometimes imperfect and poorly sealed in wet seasons, but well filled. Green husk very thin. Flavour very good, both when fresh and when dried.

Lady Irene (P169).

The original tree is at Dartford, Kent.

Tree. Large and vigorous, very vigorous in the nursery. Rather subject to Bacterial Blight (*Xanthomonas juglandis*). Leafs out at mid-season. The young growths are very red in spring.

Leaves. Very large, dark blue-green. Lateral leaflets oblong, flat ; terminal leaflet large, pointed, tapering to base. Lateral veins almost at right angles to midrib. Rachis stout.

Flowers. Protandrous. The dormant catkins are of medium size, fairly long, pointed ; medium sized when shedding pollen. Pistillate flowers large, borne in pairs or in threes.

Nuts. Large, oblong, with parallel sides and a square base. Shell of medium thickness, unevenly ridged and furrowed, well sealed, well formed even in wet seasons. Green husk very thick. Flavour good.

Leeds Castle (P168).

The original tree is at Leeds Castle, Maidstone, Kent, and was selected as a pickling nut.

Tree Very large and vigorous, very vigorous in the nursery. Leafs out at mid-season. The young shoots have little red colouring in spring.

Leaves. Medium to small, medium green. Leaflets oval, with rolled up and often wavy margins. Rachis long, yellow-green.

Flowers. Protogynous. The dormant catkins are long, narrow and pointed. When shedding pollen they are very long and narrow, hanging straight down. Pistillate flowers borne in clusters.

Nuts. Medium to small. Shell of medium thickness, bright coloured, well sealed, moderately well filled. Nuts often borne in clusters. Flavour moderate. A good nut for pickling when green.

Northdown Clawnut (P170).

The original tree is at Northdown, Margate, Kent.

Tree. Medium sized, leafing out at mid-season. The young shoots are very red in spring.

Leaves. Very large, dark blue-green. Lateral leaflets oval, slightly rolled up at the margins ; terminal leaflet large, broad. Lateral veins at a fairly acute angle to the midrib.

Flowers. Protandrous. Flowers regularly, even when young. The dormant catkins are of medium size and broad. When developing in the spring they are often quite red. When shedding pollen they are of medium size and fairly broad. Pistillate flowers borne in clusters, usually three to six flowers in a cluster. Hairs on the pistillate flowers conspicuously crimson.

Nuts. Very large, oval-oblong, with a blunt apex. Very attractive appearance. Shell thin, smooth, bright coloured, well sealed, exceptionally well filled for so large a nut. Flavour good. Green husk usually with some russeting. Nuts often borne in clusters. Crops regularly and well. The best of the very large nuts.

Patching (P149).

The original tree is at Patching, Sussex. This is another variety selected as a pickling nut.

Tree. Medium sized, leafing out early mid-season. The young shoots have little red colouring in spring.

Leaves. Medium to small, rather light green. Leaflets oval, hanging down, with rolled up margins. Rachis slender.

Flowers. Protandrous. The dormant catkins are long and pointed. When shedding pollen they are medium to long. Pistillate flowers borne in large clusters, the terminal ones of a cluster often failing to develop.

Nuts. Medium sized, oval, pointed. Shell of medium thickness, with a prominent sutural ridge, pale in colour, well sealed, well formed even in wet seasons, moderately well filled. Early ripening. Nuts often borne in large clusters. A good nut for pickling.

Secrett (P150).

The original tree is at Twickenham, Middlesex.

Tree. Medium sized. Head of tree round, dense, compact. Leafs out at mid-season. The young shoots are very red in spring.

Leaves. Medium to large, dark green. Leaflets broad, oval-oblong, hanging down, with rolled up margins. Veins light coloured, lateral veins almost at right angles to the midrib. Rachis fairly long.

Flowers. Protogynous. The dormant catkins are medium to small, narrow, pointed. When shedding pollen they are large and broad. Pistillate flowers borne in pairs.

Nuts. Large, obovate, broadest near the tip, apex blunt. Shell moderately thin, bright coloured, attractive appearance, well sealed, well formed even in wet seasons, well filled. Flavour good.

Stutton Seedling (P171).

The original tree is at Stutton, Ipswich, Suffolk.

Tree. Moderately vigorous, upright when young. Rather subject to Bacterial Blight. Leafs out at mid-season. The young shoots have little red colouring in spring.

Leaves. Medium to small sized, medium green. Leaflets oval, upfolded along the midrib.

Flowers. Protandrous. The dormant catkins are of medium size, and broad. When shedding pollen they are short and broad. Pistillate flowers usually borne in threes, stigmas red tipped even when mature.

Nuts. Very large, oval or rectangular, with a blunt apex. Very attractive appearance. Shell usually smooth, rather thick, well sealed, fairly well filled. Flavour good, especially when dried, stores well. Crops well.

Summary.

Descriptions are given of 16 walnut varieties, including eight selected English varieties.

References

Batchelor, L. D. (1929). Walnut culture in California. *Bull. Calif. agric. Exp. Sta.*, 379 (revised).

Delbard, G. (1947). Les Beaux Fruits de France. *Paris.*

Glenn, E. M. (1947). Growing walnuts in England. *Rep. E. Malling Res. Sta. for 1946*, 160-4.

——— and Witt, A. W. (1946). Progress report on the walnut variety collection at East Malling. *Rep. E. Malling Res. Sta. for 1945*, 70-4.

Hamond, J. B. (1936). Results of walnut research work at East Malling Research Station. *Rep. E. Malling Res. Sta. for 1935*, 228-31.

Roy, H. (1938). La culture du noyer dans l'Isère. *Progr. agric. vitic.*, **109**, 441-5, 462-5.

Witt, A. W. (1938). A survey of the investigations on the propagation and testing of walnuts at the East Malling Research Station. *Rep. E. Malling Res. Sta. for 1937*, 259-65.

A PROGRESS REPORT ON EXPERIMENTS WITH RABBIT REPELLENTS

By E. G. COKER

Introduction.

Precautions against rabbits are important in any fruit-growing undertaking, and it is usual to fence each plantation with rabbit-proof wire netting or to encircle each tree with a wire guard. Whichever method is adopted the cost is high ; furthermore, the light gauge netting now available does not last long, and once it begins to deteriorate rabbits find the weak places and damage to trees results. For some time rabbit repellent paints have been available, but most of these are inconvenient to use, are ineffective or damage the trees. It would be valuable to have a really safe, effective repellent, even if it were used only as a supplement to the usual wire netting fence.

In the autumn of 1949, therefore, samples were obtained of three possible rabbit deterrent materials made in the U.S.A. The first was a proprietary deer repellent compound, the second an aqueous suspension of zinc dithiocarbamate and polyethylene polysulphide, and the third the U.S. Fish and Wild Life Service compound 96A. The latter contains copper carbonate, copper sulphate and dry lime-sulphur, together with bitumen emulsion and resin as adhesives, and ethylene dichloride as a thinner.

Test of efficiency of repellents when applied to woody shoots.

On 8th February, 1950, one-year-old shoots, prunings of Cox's Orange Pippin, were tied in bundles of ten to form the treatment units. Five bundles were treated by dipping into the appropriate liquid, and five were untreated as controls. The bundles were laid out in a 5×4 Balanced Three-Fold Classification (Pearce and Taylor, 1948) on a piece of rabbit infested coppice land. The same arrangement was repeated in another part of the coppice, and in summarizing the records, the appropriate figures for corresponding plots of the experiments were added together. The shoots were observed weekly from 8th February to 1st March.

Damage consisted of small areas of bark removed in the form of individual bites, and whole tips of shoots bitten off. These were recorded separately. The statistical analysis for each type of injury showed that the treatment with 96A gave significantly better results than did the other treatments, which did not differ significantly among themselves. (Table I.)

TABLE I.

EXTENT OF RABBIT DAMAGE TO TREATED PRUNINGS.

Treatment.	Number of bites on bark.	Number of tips bitten off.
U.S. F. and W.L.S. 96A	0·2	1·8
Proprietary deer repellent	4·2	4·3
Zinc dithiocarbamate and polyethylene polysulphide	5·5	4·5
Control untreated	6·0	4·6

Differences not significant at the $P = 0{\cdot}05$ level are bracketed in this and subsequent tables. The above figures are means per bundle of ten shoots.

Effect of Compound 96A on the bark of young trees.

Small trials were started subsequently to assess the effect of applying compound 96A to the bark and buds of apple trees.

The effect upon bud development and shoot growth was determined on six two-year-old rooted stocks of M.XVI, M.XIII, M.X, M.XIV, and Ivory's Double Vigour (I.D.V.).

Young shoots less than 6 cm. in length were removed and one-third, by measured length, of all other shoots was cut away to encourage buds on one-year shoots to grow out. A record was made of the remaining length of each one-year shoot and the number of buds upon it. Within the six trees of each clonal stock, three trees, selected at random, were painted with 96A, and three left unpainted. In painting the buds, the bark and cut ends were covered. The treatment was carried out on 15th April, 1950, and on the clones used the buds were still unopened at this time. On 31st May a record of the length of young shoots was made. From 3rd-5th October records were made of the number and length of all shoots produced during the season. Some bark-splitting occurred, and this was also recorded.

Results.

The numerical data were transformed to their logarithms (Pearce, 1943). In tables II and III the actual values are given, and where the above method of analysis showed differences not significant at the level of $P < 0{\cdot}05$, the means are bracketed.

TABLE II.

MEAN TOTAL SHOOT GROWTH PER TREE, 31ST MAY, 1950.

Treatment.	Stock.				
	M.XVI.	M.XIII.	I.D.V.	M.X.	M.XIV.
Treated 96A	7·9	56·6	7·3	47·1	11·9
Control	4·5	45·6	17·2	53·5	152·1

At this time the treatment appeared to have had a slightly beneficial effect on the shoot growth of M.XVI, and a deleterious effect on Ivory's Double Vigour and M.XIV. The difference between the figures for M.XVI, only just reaches the level of significance, and the effect is doubtful.

TABLE III.

MEAN TOTAL SHOOT GROWTH PER TREE, 3RD OCTOBER, 1950.

Treatment.	Stock.				
	M.XVI.	M.XIII.	I.D.V.	M.X.	M.XIV.
Treated 96A	491	458	387	354	257
Control	316	364	422	532	1,132
Ratio $\frac{\text{Treated}}{\text{Control}}$	1·55	1·26	0·92	0·67	0·23

It will be noted that, as arranged, seasonal shoot growth increases in a regular order from M.XVI to M.XIV on the controls. On treated trees the order is exactly reversed. Many varieties of rootstock were already in leaf, but those selected were, superficially, still dormant. The observed differences in injury might be explained on the basis of slight variations in the dormancy of the various rootstocks, a suggestion that is supported by the fact that reduction of growth during the whole season was greatest on those stocks which had made most growth by the end of May.

No significant differences between rootstock or treatments were found in the percentage of buds that developed, nor was there any significant effect of treatment on the number of cases of bark-splitting. However, in October it was observed that the end bud of the laterals cut back and painted with 96A in April had sometimes failed to grow and had died back to the second bud. (Table IV.)

TABLE IV.

NUMBER OF TERMINAL BUDS FAILING TO DEVELOP.

Treatment.	Stock.					
	M.XVI.	M.XIII.	I.D.V.	M.X.	M.XIV.	Totals.
Treated 96A	nil	3 in 8	5 in 7	nil	7 in 11	16 in 47
Control	nil	1 in 9	nil	nil	nil	1 in 49

Effect of Compound 96A on wounds on apple trees.

Pieces of bark 27 mm. square were cut, in pairs, from the branches of a mature apple tree of Grenadier, at a point where the branch circumference was about 6 inches. On 23rd May, 1950, one of each pair of wounds was painted with 96A, and the other was smeared with vaseline as a control.

Where 96A had been used, death of the cambium and bark took place beyond the transverse edges of the wound. This death was not observed on the wounds treated with vaseline. Later the death of tissues ceased to extend, and a pad of callus began to grow over the exposed wound.

Measurements made on 11th October are summarized in Table V, the differences being highly significant ($P < 0.001$).

TABLE V.

DEGREE OF DAMAGE AND OF HEALING.

Treatment.	Mean length of dead bark. mm.	Mean width of unhealed area. mm.
96A	10·2	17·19
Vaseline	0·4	19·81

It is not possible to assess whether the result is due to a stimulation of callus formation by 96A or a retardation by vaseline.

The fact that bark killing took place only above and below the wound suggests that some toxic component in the 96A might be moving through the tissue of the cambium or phloem. It is possible that damage might not occur if 96A were applied before the cambium commences active division.

On the basis of these experiments 96A appears to be very promising, though further trials are needed before it could be recommended for general use.

Acknowledgements.

The author thanks Mr. W. Taylor of the British Embassy, Washington, U.S.A., for obtaining these materials ; the Statistics Section for help in the design of the experiments and for carrying out the analyses, and Dr. W. S. Rogers and Dr. H. B. S. Montgomery for much help and advice.

Summary.

Three potential repellents, obtained from the U.S.A., were tested on bundles of apple shoots. The only substance that showed promise as a repellent was compound 96A of the U.S. Fish and Wild Life Service.

This preparation was found to cause only slight injury to two-year-old rooted layers of five clonal apple stocks, but evidence was found that damage resulted from application to cut surfaces or wounds.

REFERENCES

PEARCE, S. C. (1942-3). The statistical interpretation of vigour measurements of fruit trees. *J. Pomol.*, **20**, 111-15.

PEARCE, S. C. and TAYLOR, J. (1948). The changing of treatments in a long-term trial. *J. agric. Sci.*, **38**, 402-10.

WEATHER CONDITIONS DURING 1950

By A. P. PRESTON

Following an exceptionally dry and sunny year, 1950 has been comparatively uneventful except for October which set up a record as the driest since our records began in August, 1914. Total rainfall was above the average by 1·11 inches and also sunshine by 175·4 hours.

Snow and sleet were recorded on five occasions in January and February, but did not settle for more than an hour or two. February had a rainfall 2·38 inches above the average and a warm spell occurred during the middle of the month when screen maxima of 61° F. were recorded twice.

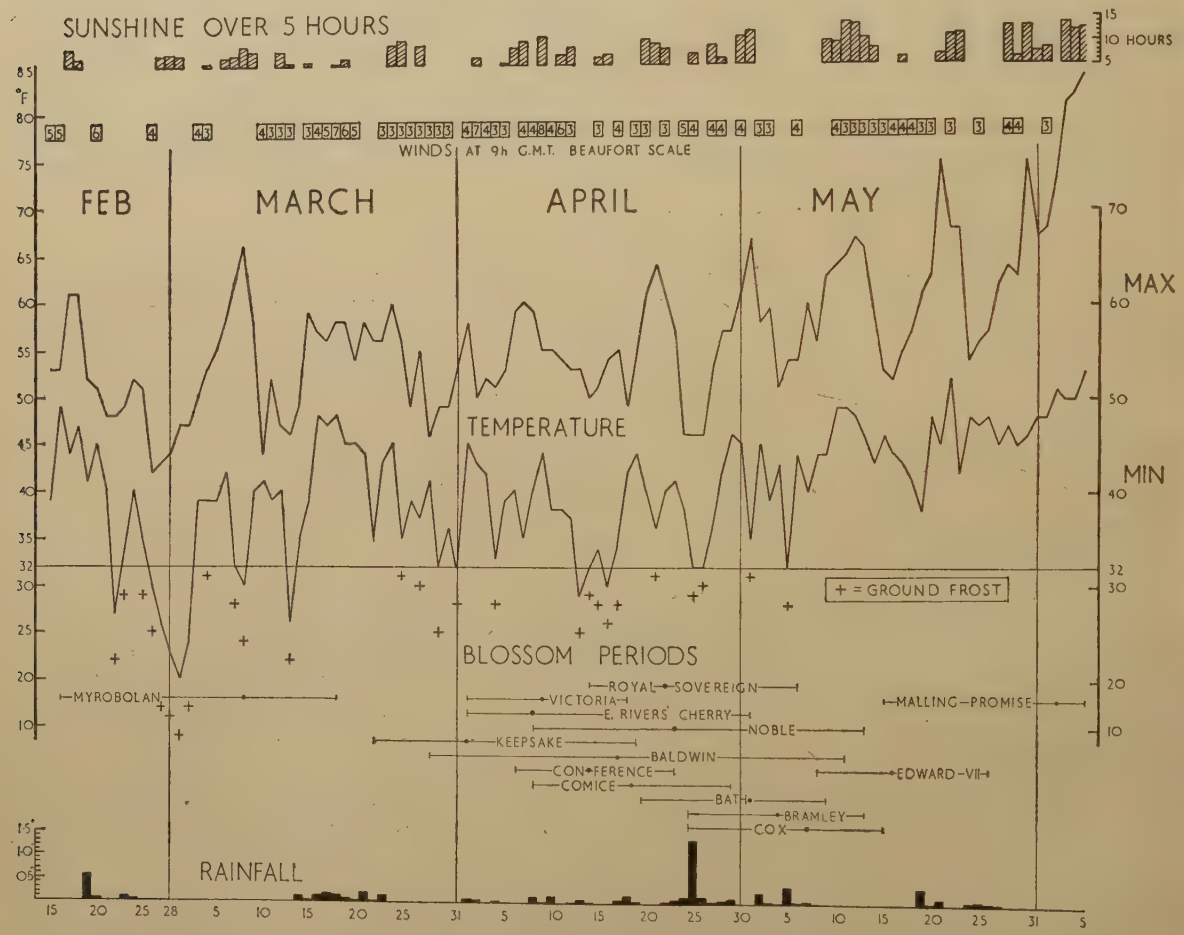


Diagram to show the weather recorded during the Blossoming Season, 1950.

Cold northerly winds during the latter part of March coincided with the first plum blossoms while the strong westerly winds during April were unfavourable for regular visits by honeybees to cherries. Also during April rain was recorded on twenty days and snowfalls on 24th, 25th and 26th, reached a depth of 4 inches on level open ground. The weight of snow broke many cherry boughs which were in full bloom at the time and flattened black currant bushes which were also in leaf and flower. This is the third time we have recorded snow at blossom time, the first was in 1919 and more recently in 1945.

Serious late spring frosts were again absent this year. There was one ground frost recorded in May when the grass temperature fell to 28° F. Light winds were recorded almost daily and coming from the north-east during the middle of the month they gave cool conditions during the latter part of the apple blossom period.

June, a sunny month, had only one day without recorded sunshine and temperatures were high during the first and last weeks when the screen maximum temperature was over 80° F. on five occasions. The Meteorological Station was raided by magpies during the early morning of the 16th, upsetting the exposed thermometers.

July was warm and showery ; the rainfall recorded on nineteen days was just above the average. The screen temperature reached 80° F. only once this month and once in August. The first half of August was warm and dry and the latter part was cool and wet. Rain fell on seventeen days though the total for the month was just below the average.

September was showery and cool, rain being recorded on twenty-two days. There were no ground frosts. We recorded the driest October, since 1914, with a rainfall of 0·17 inches, 2·65 inches below the average. Rain fell on six days only. November was very wet ; rain was recorded on twenty-three days giving a total of 5·85 inches. This is not a record as 5·88 inches were recorded in November, 1929.

Cold, snowy conditions prevailed during December. Snow was first recorded on 3rd and on nine other days during the month. The ground in the neighbourhood of the station was snow covered on eight days at the time of observation, while on level ground the snow reached a depth of 3 inches on the 17th. The grass thermometer fell to 9° F. on the 5th. In the screen the monthly mean maximum temperature was 10° lower than for December last year while the mean minimum temperature was 7° lower.

Newlands Farm, Throwley.

This crop weather station, a sub-station of East Malling, has completed its first year. Owing to the acute shortage of thermometers it is still without a maximum screen thermometer. Rainfall, sunshine and some temperature figures for this station appear in the summary beneath those from East Malling.

Acknowledgements.

The writer wishes to thank Mr. G. F. Trowell for assistance during the year and members of the Statistical Section who computed the data and prepared the diagram. Mr. J. Cronk (by courtesy of T. Neame, Esq.) was responsible for recording observations at Newlands Farm and his co-operation is gratefully acknowledged.

SUMMARY OF METEOROLOGICAL OBSERVATIONS DURING 1950.

EAST MALLING.

Month.	Temperature in Screen.					No. of Ground Frosts.	Rainfall.			Sunshine.			Soil Temperatures.			
	Mean maximum.	Mean minimum.	Highest.	Lowest.	Mean.		Total in inches.	Heaviest fall in a day.	30 years' average.	Total hours.	Average per day.	30 years' Average.	4 inches.	8 inches.	2 feet.	4 feet.
January	44	34	53	21	39	17	1·28	0·62	2·53	53·8	1·7	45·8	38·4	39·4	42·2	45·1
February	49	37	61	23	43	13	4·20	0·87	1·82	71·1	2·5	67·3	40·0	40·8	42·1	43·3
March ..	53	38	66	20	45	7	1·06	0·20	1·52	134·3	4·3	118·7	43·3	43·5	44·8	45·0
April ..	54	38	64	29	46	8	2·66	1·36	1·99	168·1	5·6	131·7	45·8	45·4	47·1	47·1
May ..	61	44	75	32	52	1	1·43	0·39	1·77	187·9	6·1	198·3	54·4	53·2	53·0	50·5
June ..	72	51	85	42	61	0	1·25	0·61	1·44	280·4	9·3	204·0	66·1	64·4	63·0	57·9
July ..	70	53	81	43	61	0	3·08	0·47	2·20	213·9	6·9	190·7	64·6	63·8	64·3	60·9
August ..	70	51	80	42	60	0	2·22	0·70	2·27	203·0	6·5	181·9	63·6	63·0	64·1	61·9
September	63	49	72	41	56	0	2·09	0·32	2·08	131·7	4·3	145·8	56·7	57·0	59·1	59·4
October ..	57	41	69	26	49	5	0·17	0·10	2·82	121·2	3·9	100·9	48·6	49·9	53·2	55·3
November	49	37	58	26	43	10	5·85	1·23	3·15	66·6	2·2	53·7	41·8	42·9	45·8	49·3
December	38	29	52	19	33	22	2·06	0·35	2·65	21·3	0·7	39·1	34·7	35·8	39·7	44·1
Totals ..						83	27·35		26·24	1653·3		1477·9				

SUB-STATION, NEWLANDS FARM, THROWLEY.

January		33		20		13	1·88	0·82		50·6	1·6		38·0	39·0		
February		36		28		8	4·93	0·98		82·2	2·9		39·4	40·2		
March ..		39		26		8	0·98	0·19		133·9	4·3		42·6	43·2		
April ..		38		30		5	2·42	0·90		160·3	5·3		44·0	44·5		46·2
May ..		44		36		0	1·80	0·59		175·2	5·7		51·6	51·2		48·5
June ..		52		45		0	1·50	0·55		286·8	9·6		62·1	61·1		54·1
July ..		54		47		0	3·05	0·47		215·0	6·9		62·9	62·4		57·7
August ..		53		47		0	1·87	0·49		216·4	7·0		61·5	61·5		59·1
September		50		43		0	2·13	0·29		132·6	4·4		55·9	56·6		58·1
October		44		30		5	0·39	0·09		131·2	4·2		48·8	50·3		55·0
November		38		30		6	6·69	1·01		71·8	2·4		42·0	43·3		50·1
December		29		20		23	3·26	0·54		37·6	1·2		34·6	35·9		45·2
Totals ..						68	30·90			1693·6						

STATISTICS

THE ESTIMATION OF FRUIT SIZE OF CHERRIES BY SAMPLING METHODS

By J. TAYLOR

Introduction.

In experiments with fruit trees it is frequently necessary to measure the average size of the fruit per tree under different experimental treatments. Market grades have been found impracticable for this purpose and fruit size has usually been expressed at East Malling as the " weight of 100 fruits " or alternatively as the " number of fruits in 1 lb." Unless crops are small, it is essential to use sampling methods to arrive at these quantities and suitable methods for apples, pears and plums have already been described by Pearce (1947). The present paper describes a study of sampling methods for fruit size in cherries carried out in 1949 and 1950.

1. Description of trees and of methods of picking.

Trees of four varieties were used in the investigation, as follows :

Sweet cherries.

Bigarreau de Schrecken and *Turkey Heart.*—These were standard trees in a trial of sweet cherries on clonal Mazzard rootstocks, planted in December, 1928. The Plot is also used for a comparison of clean cultivation with grass cover cropping. For the purpose of the investigation the trees were divided into groups, all within a group being on the same rootstock and having the same cultural treatment. Attention was concentrated on the groups that contained most trees.

The fruit was picked into half-bushel boxes (holding 24 lb. approximately). Some trees were picked by one man and some by two. Bigarreau de Schrecken was included in the investigation in 1950 only.

Acid cherries.

Kentish Red.—These were bush trees in a separate trial of selected clonal Mazzard rootstocks. They were all planted in March, 1928, save for one of the trees sampled in 1949, which was planted in February, 1927. The trees were divided into groups according to rootstock.

The fruit was picked into 12 lb. chip baskets. In 1949 the number of pickers on a tree varied between two and six ; in 1950 it was two.

Morello.—These were bush trees on clonal Mazzard and Mahaleb rootstocks, planted in 1923 and 1924. Some of the trees used in 1949 had received different spray treatments, but this should not affect the usefulness of the records for the purpose to which they were put. The trees used in 1950 had all been treated alike, and were grouped according to rootstock.

The fruit was picked into 12 lb. chips, with more than one picker on each tree. In 1950, unlike the other varieties, they were picked without stalks.

2. Types of sample.

Two methods of sampling were used during the course of the experiment, details of which are given below.

" Layer " samples.

Except for some from the Morellos, all 1949 samples were of this type. A sample consisted of 100 fruit taken as a layer from the top of the container. Some containers were recorded completely by taking successive layers all the way down.

It is not easy to take a layer sample properly, for two reasons. If there are notable differences in shade between the fruits, the eye tends to be attracted by and to select first the more highly coloured

ones. Also cherries are often picked in clusters of two or three, and one fruit of a cluster may be on the surface and others beneath it. So far as order of picking is concerned, such a cluster belongs to the level of its lowest fruit, but it is usually sampled at the level of the highest one.

" Grab " samples.

Some Morello samples in 1949, and all samples in 1950, were taken by " grabbing " fruit from the top of the container, with one or both hands. Such a sample includes fruit of several layers. If insufficient fruits were obtained by the first grab, more were taken from the same part of the container. The 1949 samples consisted of 100 fruit, to be comparable with the layer samples. In general it is more convenient for a grab sample to be of a specified weight, the number of fruit being counted. In 1950 a grab sample of 1 lb. was counted and then followed by a second one, so taken that together the two would be equivalent to a single grab sample of 2 lb.

In 1949 cherries that had lost their stalks, or were badly rotted, were excluded from the sample. This made little difference with Kentish Red and Morello, but with Turkey Heart about a quarter of the fruit had to be excluded. In 1950 all fruit were included whatever their condition, as this would be done in routine field sampling and it was desired to reproduce the conditions of this as far as possible.

3. Variation within a container.—Evidence from layer samples.

In 1949 eleven chips of Kentish Red and nine boxes of Turkey Heart were sampled completely, successive layers of 100 cherries being taken and weighed. There were on the average eighteen layers in a chip of Kentish Red and twenty layers in a box of Turkey Heart. A statistical test* showed that the weights of the layers could not be regarded as randomly ordered, but that there was a correlation between adjacent ones.

The possibility of representing each container by a sample consisting of the top layer of 100 cherries was investigated. The weight of such a sample will usually differ from the mean weight per 100 cherries for the container as a whole ; but, if the differences average zero over all containers, samples of this type will be unbiased.

The differences were calculated for each container sampled, and the mean values (m_1) and standard deviations (σ_1) of these differences are given in Table I. m_1 provides an estimate of the *mean bias* of samples of this type for each variety. Even if the samples are unbiased m_1 may not be exactly zero because it has been estimated from a small number of containers. Tests of significance were, therefore carried out. In the case of Kentish Red, m_1 is zero to three places of decimals and does not differ

TABLE I.

SAMPLING OF CONTAINERS, 1949.

Variety.	Number of containers sampled.	Mean weight of 100 cherries. (lb.)	Method of sampling.	Mean difference between sample and container.		Standard deviation.	
				m_1	m_2	σ_1	σ_2
Kentish Red ..	11	0·613	Layer	0·000	0·000	0·030	0·024
Turkey Heart ..	9	0·901	Layer	+0·031	+0·020	0·033	0·027
Morello	18	1·348	Layer	+0·002	—	0·068	—
Morello	18	1·348	Grab	+0·003	—	0·035	—

significantly from it, so the top 100 give an unbiased estimate of the container as a whole. In the case of Turkey Heart, m_1 is significantly different from zero, but it will be seen that it is only 3·3 per cent of the overall mean weight of 100 cherries, so the bias is small.

The difference between the mean weight of the two topmost hundreds and the mean weight per hundred for the whole container was also calculated, and the mean values (m_2) and standard deviations (σ_2) are also given in Table I. m_2 is not significantly different from zero for either variety, but it is near the 5 per cent point for Turkey Heart.

It is worth considering how the top layers can provide an unbiased sample when they are certainly not a random sample. Pickers usually strip part of a tree, putting the fruit in a basket, then empty the

* The mean-square successive difference test (von Neumann *et al.* (1941), Hart (1942)). For six chips of Kentish Red and eight boxes of Turkey Heart this showed significance at the 5 per cent level. The statistic $\frac{\delta^2}{S^2}$ was only greater than its 50 per cent point for two containers out of twenty.

basket into a box or larger basket and proceed to another part of the tree. The fruit size may well vary between parts of trees so that each picker's basket will provide a fairly homogeneous batch. The overall correlation between adjacent layers, without a general trend from top to bottom, is due to the layers within a batch being closely similar, followed by a change to layers which may be either heavier or lighter. (When more than one picker is working on a tree there will be little correlation between successive batches.) Thus there will generally be an even chance of the top layer being heavier or lighter than the mean.

Comparison of layer and grab samples.

The study of layer samples has thrown useful light on the problem, but for routine work grab samples are easier to take. A comparison of the accuracy of the two methods was made in 1949 on Morellos. Eighteen chip baskets were used. A layer sample of 100 fruit was taken from each, weighed and replaced on the top of the chip. A grab sample of 100 fruit was then taken and weighed, after which the remaining fruit were counted and weighed, so that the mean weight of 100 fruit for the whole container could be calculated. Values of m_1 and σ_1 were calculated as before and are given in Table I. Neither value of m_1 differed significantly from zero. σ_1 is significantly smaller for the grab sample than for the layer sample.* Thus the grab sample gave a closer estimate of the container as a whole than did the layer sample.

1950 grab samples.

In 1950 several containers of all four varieties were sampled, the numbers used being given in Table II. The number of fruit to the pound was calculated for each of two grab samples, taken as described above, and for all the fruit in the container. The first grab sample and the mean of the two samples were then in turn compared with the mean for the whole container. The mean differences m_1 and m_2 and the appropriate standard deviations σ_1 and σ_2 are given in Table II.

The mean values of the differences were not significantly different from zero except for Morello for which m_2 is significant but m_1 is not. Even here the estimated mean bias is only 2·5 per cent of the mean number of fruits per lb. Morello may be the exception because it was the only variety picked without stalks, so it would be easier for small fruit to slip towards the bottom of the container. A *negative* bias means there are fewer fruit per lb. at the top, and so they are heavier than the remainder.

TABLE II.

SAMPLING OF CONTAINERS, 1950.

Variety.	Number of containers sampled.	Mean number of cherries per lb.	Method of sampling.	Mean difference between sample and container.		Standard deviation.	
				m_1	m_2	σ_1	σ_2
Schrecken ..	20	64·4	Grab	−0·16	−0·49	2·19	1·66
Kentish Red ..	28	147·6	Grab	+0·12	−0·35	5·17	4·44
Turkey Heart ..	31	100·9	Grab	−0·34	−0·61	5·02	3·75
Morello	16	60·2	Grab	−1·33	−1·48	2·96	2·50

Both in 1949 and 1950, the difference between a sample and the mean value for the whole container was never significantly correlated with the mean value for the whole container. This contrasts with the results for apples (Pearce, 1947), for which there was a bias which depends on the mean size. It means that samples from the tops of containers may confidently be used for comparisons within a variety, even though there may sometimes be small biases affecting all containers of a variety on a plot.

It will be seen that the standard deviations are small in comparison with the mean numbers of cherries per lb. This point is of importance in section 5.

4. Variation between containers and trees.

In 1949 seventeen trees of Kentish Red and twenty-three of Turkey Heart were selected and the weights of the top two layers of 100 fruit were determined for every full container.

* A test due to Hotelling (1940) was used.

The variation between the values obtained can be represented by four components. There are differences between groups of trees. There are differences between trees within a group, considering each tree as a whole and averaging over all containers. The standard deviation of these differences is denoted by σ_t.* There are differences between containers within a tree, considering each container as a whole. The standard deviation of these differences is denoted by σ_c*. Finally there are differences between the top layers and the container as a whole, which have been discussed and estimated in section 3.

Analyses of variance carried out on the results enabled estimates to be made of σ_c and σ_t by the " components of variance " method. These are given in Table III, and show a rather higher variation between trees than within trees.

TABLE III.

VARIATION BETWEEN CONTAINERS AND TREES, 1949.

Variety.	Number of groups of trees.	Total number of trees sampled.	Mean number containers per tree.	Standard deviations of weight of 100 fruit (lb.)	
				σ_c	σ_t
Kentish Red ..	6	17	6·4	0·012	0·047
Turkey Heart	6	23	6·0	0·037	0·058

Picking extended over six days for the Kentish Reds and eight days for the Turkey Hearts. A test was made whether the size of the fruit on a tree was correlated with the date of picking, but no indication of a correlation was found.

In 1950 two 1 lb. grab samples were taken from every container of some trees of Schrecken and Kentish Red. For Turkey Heart and Morello the record was made on not more than three containers from each tree, as this enabled more trees to be sampled in the time available. Where there were more than three containers at least three-quarters full, the three to be sampled were chosen at random. The values of σ_c and σ_t are given in Table IV. It must be noted that the basis of calculation is different from that in Table III, being the number of fruit in 1 lb. and not the weight of 100 fruit.

TABLE IV.

VARIATION BETWEEN CONTAINERS AND TREES, 1950.

Variety.	Number of groups of trees.	Total number of trees sampled.	Mean number containers per tree.	Standard deviation of number of fruit per lb.	
				σ_c	σ_t
Schrecken ..	6	20	3·3	1·94	2·00
Kentish Red ..	6	28	3·9	0·00†	11·14
Turkey Heart..	8	31	2·6	2·45	5·74
Morello	4	16	2·2	1·46	6·19

† The customary rule of estimation would here make σ_c^2 negative. This is impossible, but the true value of σ_c^2 must evidently be very small so it has been taken to be zero.

The trees of Morello sampled were all picked on the same day, so they provide no information on relations between picking date and size. Schrecken was picked over six days and Turkey Heart over nine days, and for each of these varieties there was a significant decrease in the number of fruit per pound as time passed. Such an increase in size is normally to be expected as the fruit swell. Probably it was not noticeable in 1949 because of the long dry spell at picking time. In 1950 there were several showers at this time and some fruit were splitting.

* It is assumed throughout that σ_t and σ_c, also σ_1 and σ_2, have the same value for all groups of trees of the same variety. There is some evidence that this is not always so, but in that case the values quoted can be taken to indicate typical values. The general conclusions would not be changed if different values were taken for different groups.

The result for Kentish Red was unusual, however. Picking only took three days, but there was a significant *increase* in the number of fruit per pound as time passed. No fully satisfactory explanation of this has been found. These trees were shaded to varying degrees, and it may have been that the fruit from some of the later picked was less ripe, and therefore probably smaller than that from trees picked earlier.

Thus the results for three varieties in this year suggest that σ_t could be reduced if the picking of a variety could be completed in a shorter time. With large orchards this is difficult and picking over several days must be accepted. However, variability could be somewhat reduced if it were possible to pick a complete replicate (e.g. a block containing one tree of each treatment) at a time. The variability of crop weight could probably be reduced by the same means.

5. Sampling method.—Bias.

It has been shown that a grab sample from the top of a container gives an estimate of the mean size of fruit in the container that is unbiased, or at the worst has a small bias that is uncorrelated with the mean size and so will not affect the validity of comparisons of treatments on trees of one variety. It follows that a grab sample from every container for a tree, or from a few containers sampled at random, will give an unbiased (or only slightly biased) estimate of the mean fruit size for the tree as a whole.

Variability.

If such an estimate is used the differences between similarly treated trees will appear to be rather greater than they actually are, because of the variation introduced by sampling. Table IV gave estimates of σ_t, the actual tree-to-tree standard deviation in 1950. The standard deviation between trees when each is represented by a grab sample of 1 lb. from each of $2n$ randomly selected containers will be written $\sigma_{t'}(2n)$ and the standard deviation between trees when each is represented by a grab sample of 2 lb. from each of n randomly selected containers will be written $\sigma_{t''}(n)$.

Using the figures in Tables II and IV it is possible* to estimate $\sigma_{t'}(2n)$ and $\sigma_{t''}(n)$, for the 1950 crops. Fig. 1 shows the values for Turkey Heart, for total sample sizes up to 6 lb. per tree. The values are plotted against the total weight of sample, and it will be seen that for a given total weight it is better to take 1 lb. per container sampled than 2 lb. from half as many containers. This result has also been found for each of the other varieties.

Discussion and recommendations.

The broken line on Fig. 1 denotes σ_t, which is the lower limit to which $\sigma_{t'}$ and $\sigma_{t''}$ would approach if a large number of containers could be sampled. For a total weight of sample of 2 lb. per tree or more, the samples do not give values very much greater than σ_t, so should be acceptable on the score of variability. It is desirable that a sample should be divided between two containers at least, because recorders are unlikely to select containers strictly at random during routine sampling, and there is less risk of bias if more than one is taken. Attention is therefore directed to the method of taking a 1 lb. sample from each of two containers. Table V gives the values of $\sigma_{t'}(2)$ and their ratios to σ_t. It also gives σ_t and $\sigma_{t'}(2)$ as percentages of the mean number of fruit per pound for the variety as a whole, i.e. coefficients of variability if a complete record is made and if a sample of this type is taken. For Kentish Red and Morello $\sigma_{t'}(2)$ is little greater than σ_t. For Schrecken and Turkey Heart the proportionate increase is greater, but as the coefficient of variability remains under 10 per cent the apparent tree-to-tree variation is still low enough for moderate treatment differences to be significant in trials with a few replicates. The high proportionate increase for Schrecken is due to the very low value for σ_t.

It was mentioned in the previous section that σ_t would have been less in 1950 if picking took fewer days, or if a complete replicate were picked at a time. As the sampling errors would be the same in absolute value they would be greater proportionately, but $\sigma_{t'}(2)$ would be smaller.

The 1949 data can also be used to obtain the coefficient of variability of the " weight per 100 fruit " if layer samples are taken. For Kentish Red the coefficient of variability with a complete

* Using the formulae

$$\sigma_{t'}(2n) = \left\{\sigma_t^2 + \frac{1}{2n}(\sigma_c^2 + \sigma_1^2)\right\}^{\frac{1}{2}}$$

and

$$\sigma_{t''}(n) = \left\{\sigma_t^2 + \frac{1}{n}(\sigma_c^2 + \sigma_2^2)\right\}^{\frac{1}{2}}$$

record is 7·68 per cent, if a layer sample of 100 fruit is taken from two randomly chosen containers per tree it becomes 8·56 per cent. For Turkey Heart the corresponding figures are 6·43 per cent and 7·50 per cent. This confirms that quite small samples from two containers can still give low coefficients of variability.

TABLE V.

EFFECTS OF TAKING 1 LB. GRAB SAMPLES FROM TWO CONTAINERS PER TREE, 1950.

Variety.	$\sigma_{t'(2)}$ (in number of fruit per lb.)	$\frac{\sigma_{t'(2)}}{\sigma_t}$	Coefficient of variability.	
			σ_t	$\sigma_{t'(2)}$
Schrecken	2·88	1·44	3·10	4·47
Kentish Red	11·73	1·05	7·55	7·95
Turkey Heart	6·97	1·21	5·69	6·91
Morello	6·61	1·07	10·27	10·98

The calculations on which these recommendations are based have assumed random selection of containers for sampling, but it has already been said that this can hardly be expected of recorders

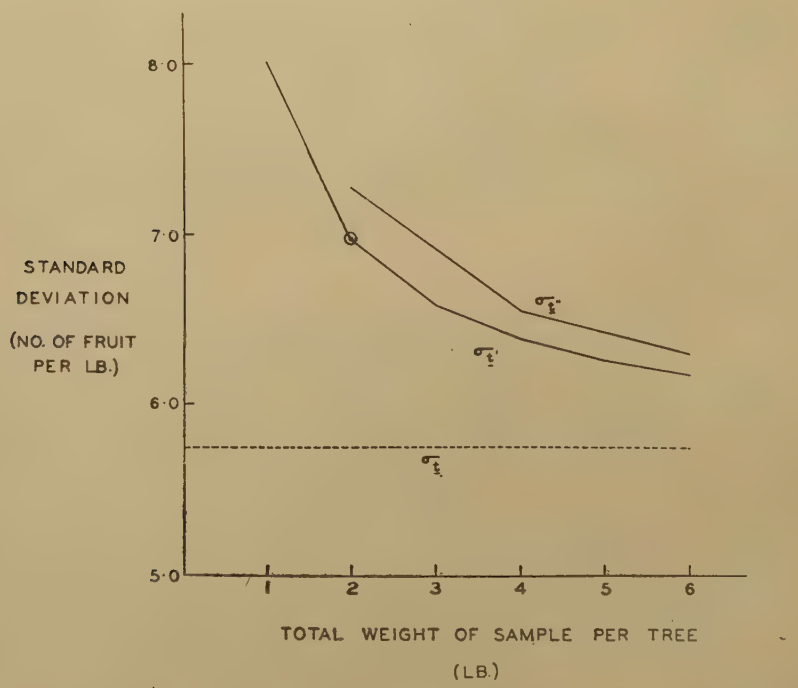


FIG. 1.

Turkey Heart 1950. Standard deviation between trees of a group, using sampling methods and with complete record. The ringed point indicates the sample recommended for routine work.

in the field. It is desirable that they should receive definite instructions and it is therefore suggested that when the use of random numbers or coin-tossing is impossible the containers should be stacked or laid out in order of picking and that the sample should be from the first and third containers if there are only three, from the second and fourth if there are four or five, and from the third and sixth if there are six or more. Although this is a systematic method, the order of picking fruits is so variable that it should give effectively the same results as the random method.

Acknowledgements.

The author wishes to thanks Dr. S. C. Pearce for much helpful discussion of the problem. He wishes to thank Messrs D. E. Barton and B. T. Warner, and also Miss V. V. Fry, for assistance in carrying out the experiments.

Summary.

The results of size sampling experiments with four varieties of cherry in 1949 and 1950 are discussed. " Layer samples " and " grab samples " from the tops of containers are described. It is found that they usually give unbiased estimates of the fruit size of the containers as a whole, and that if there is a bias it is small and uncorrelated with the size. The variability between containers and between trees is assessed. It is concluded that a good routine sampling method is to take a " grab " sample of a pound of fruit from each of two containers per tree, selected at random if possible. Accuracy might be increased by picking all trees of a replicate at about the same time.

References

Hart, B. I. (1942). Significance levels for the ratio of the mean square successive difference to the variance. *Ann. Math. Statist.*, **13**, 445-7.

Hotelling, H. (1940). The selection of varieties for use in prediction with some comments on the general problem of nuisance parameters. *Ann. Math. Statist.*, **11**, 271-83.

Pearce, S. C. (1947). The measurement of fruit crops by sampling. *Rep. E. Malling Res. Sta. for 1946*, 77-82.

von Neumann, J., Kent, R. H., Bellinson, H. R. and Hart, B. I. (1941). The mean square successive difference. *Ann. Math. Statist.*, **12**, 153-62.

STATISTICAL STUDIES ON STRAWBERRY CROP AND VIGOUR MEASUREMENTS

By J. TAYLOR

Introduction.

The principal published work on the size and shape of strawberry plots is that of Edgar (1938), who discussed the results of two uniformity trials and recommended the use of plots of about fifty plants, plots being as nearly square as possible. Since then information on variability has accumulated from comparative trials at East Malling, and the data of one of the trials which Edgar reported have been re-worked using methods recently described. The results are discussed in Part I of this paper.

In Part II, a study of the control of variability by the statistical method of " calibration " by covariance on a prior measurement (Pearce and Taylor, 1950) is described.

For many years it has been the practice at East Malling to record the spread, and often the height also, of every plant in strawberry trials, as described by Rogers (1931). A study of the correct way of interpreting these records, taking into account the effects of disease, is described in Part III.

The data analysed in this paper have all come from trials in which the rows were three feet apart and the plants eighteen inches apart in the rows. Runners were removed, i.e. the " single plant " cultural method was used.

The trials have been designated by numbers from one to twenty-five. The data of some trials were used in investigating more than one problem.

I. ARRANGEMENT OF PLOTS AND BLOCKS IN CROPPING TRIALS.

Results of a uniformity trial.

In the trial described by Edgar (1938) runners of a single Royal Sovereign clone produced at five different periods were compared in a Latin square. Each plot consisted of 48 experimental plants in four rows of twelve with an extra guard plant at each end. The trial was planted in the spring of 1933 and the plants de-blossomed in that year. In 1934 and 1935 crop weights were recorded for each individual plant.

It has been suggested (Pearce, 1950) that the method used by Edgar would be improved if optimum plot-size were worked out using a standardized number of treatments. Accordingly, the data of sixteen of the 48-plant plots have been reworked, assuming treatments to number four throughout. In Table I coefficients of variation, V, expressed as percentages, are compared for different shapes of 24-plant plots in 96-plant blocks.*

TABLE I.

COEFFICIENTS OF VARIATION OF CROP WEIGHT FOR 24-PLANT PLOTS IN TRIALS OF 4 TREATMENTS.

Year.	1934.			1935.		
Plot shape.	2 × 12.	4 × 6.	8 × 3.	2 × 12.	4 × 6.	8 × 3.
Block shape						
2 × 48†	6·6	—	—	15·5	—	—
4 × 24	6·3	7·8	—	15·3	12·2	—
8 × 12	6·6	8·0	6·3	15·5	12·5	9·2
16 × 6	—	7·6	5·8	—	14·1	11·3

† The number of rows is given first, and then the number of plants in a row.

Table I shows that V was about twice as large in 1935 as in 1934. The 1934 variability was not much affected by changes in shape of plots and blocks, but in 1935 it was least when plots extended over as *many* rows as possible and blocks over as *few* as possible. Tables were prepared also for plots of

* The treatments having been applied to 48-plant units it was necessary to allow for them by fitting parameters but this does not affect the general approach.

twelve and four plants in blocks of 48 and 16 plants respectively and these lead to the same conclusions. In 1935 there had been only a light crop on account of a severe frost in May followed by a bad attack of yellow-edge disease. For these reasons Edgar based her main conclusions on variation in 1934 crop and in height and spread, these latter being rather less variable than the 1934 crop.

Comparing different plot sizes, in both years coefficients of variation varied approximately inversely with the square root of plot-size, thus showing that information per unit area would be much the same whatever the number of plants to a plot.

Variability in comparative trials.

Since the uniformity trial more information has been obtained from several comparative trials in which the plots have measured 2 × 10, 2 × 12 or 2 × 14 plants. Table II gives the values of V for these trials, from which it appears that Edgar's plants were unusually uniform. V was generally much higher than in the uniformity trial in 1934 and indeed often exceeded the 1935 figures.

TABLE II.

COEFFICIENTS OF VARIATION (V) AND VARIANCE-RATIOS FOR BLOCKS (F) FOR ROUTINE TRIALS.

Trial no.	Winter of planting.	Year of cropping.	Plot shape.	Block shape.	V.	F.
TRIALS BLOCKED ALONG ROWS.						
1	1944/5	1946	2 × 10	2 × 20	20·6	0·22
		1947			21·8	0·78
"INTERMEDIATE" BLOCKING.						
2	1941/2	1943	2 × 12	8 × 24	17·9	2·57*
		1944			23·8	0·92
3	1942/3	1944	2 × 12	8 × 24	17·6	2·34
		1945			13·6	3·43*
		1946			36·4	6·62**
4	1943/4	1945	2 × 14	8 × 28	21·8	1·96
		1946			44·9	1·24
5	1943/4	1945	2 × 12	4 × 60	19·4	0·96
		1946			17·7	2·72
6	1945/6	1947	2 × 12	6 × 24	15·0	3·50*
		1948			9·1	0·91
7	1945/6	1947	2 × 12	6 × 24	19·3	0·36
TRIALS BLOCKED ACROSS ROWS.						
8	1943/4	1945	2 × 12	10 × 12	17·4	2·99
9	1944/5	1946	2 × 12	16 × 12	16·8	2·32
		1947			22·6	0·19
10	1944/5	1947	2 × 12	8 × 12	17·0	2·05
11	1944/5	1947	2 × 12	8 × 12	12·1	2·54
12	1947/8	1948	2 × 12	12 × 12	16·0	0·95

NOTE.—In this and in all other tables :
* denotes significance of difference at the $P = 0·05$ level.
** denotes significance of differences at the $P = 0·01$ level.
*** denotes significance of differences at the $P = 0·001$ level.

Table II shows also the variance ratios (F) for differences between blocks. These indicate the effectiveness of the blocks in reducing variability and demonstrate that error can often be partly eliminated in this way.

TABLE III.

COEFFICIENTS OF VARIATION (V), EXPRESSED AS PERCENTAGES, FOR DIFFERENT BLOCK SHAPES.

Trial no.	Winter of planting.	Year of cropping.	Plot shape.	Block shape.	V.	Block shape.	V.
13	1939/40	1941	2 × 16	2 × 80	18·3	10 × 16	13·3
		1942			21·8		19·1
3	1942/3	1944	2 × 12	4 × 48	18·2	8 × 24	17·6
		1945			16·2		13·6
		1946			38·7		36·4
4	1943/4	1945	2 × 14	4 × 56	24·8	8 × 28	21·8
		1946			45·5		44·9
14	1943/4	1944	2 × 14	2 × 84	22·7	12 × 14	18·7
		1945			23·6		17·6
15	1943/4	1945	3 × 10	3 × 60	7·3	6 × 30	8·3
		1947			25·4		26·0

These trials also provide information on the best shape of block. Table III gives for five trials the coefficients of variation for two block shapes. (Trials 13 and 14 were designed in Latin squares, so blocking by either rows or columns was possible. Trials 3, 4 and 15 were laid out in randomized blocks but, by fitting parameters, it was possible to investigate what would have happened if the blocks had been differently arranged.) In general, the more square the *block* the less the variation, which means that square *plots* would be less uniform than long, narrow ones.

Discussion.—Plot size.

Edgar recommended the use of plots of about 50 plants on the grounds that they are less variable than smaller ones. Undoubtedly this is so, but larger plots mean fewer replicates and from the point of view of making efficient use of land it does not appear that plot size is always of first importance. In the uniformity trial in 1934 plots of four, twelve and twenty-four plants were almost equally efficient on this basis while in 1935 the dominant factors were shape of plot and block.

Plot and block shape.

The questions of plot and block shape can usefully be discussed together because, in general, a shape that is good for plots is bad for blocks and *vice versa*. The reason is that blocks should be chosen so as to have as little variation as possible within them and as much as possible between them, but with plots the reverse holds. The results in this paper apply primarily to plots of about 24 plants, but there seems no reason to doubt that they would also apply to plots of other sizes.

It has been argued by Christidis (1931, 1939) and demonstrated for a wide range of species that plots give least variability when they are long and narrow, while blocks are best when square, provided soil is the chief cause of variability. (Sometimes in sowing, irregular drilling will bring about differences between rows so large that the least variable plots will be those that extend over as many rows as possible while blocks should cover as few as possible.)

From the above results there is no reason to think that strawberries provide an exception. It is true that the figures of the uniformity trial in 1935 suggest considerable differences between rows, but this may be a result of the very high yellow-edge infection (more than half the plants were diseased) having spread along rows rather than across them. If so, the results are not of general application, because such serious outbreaks are unusual. Consequently, Edgar's statement that " square plots are always more efficient than long narrow ones " seems too sweeping.

In Table II trials were classified by the system of blocking. Although significant values of F arose only with the so-called " intermediate " blocks, results were satisfactory also when the blocks were taken across the rows. Remembering that the distance of planting between rows was twice that within, it is clear that nearly square blocks were indeed best. It follows that plots should be narrow.

Recommendations as to plots and blocks.

Since it appears that a reduction of plot-size when associated with a corresponding increase in replication has little effect on error, the number of plants to a plot may be determined on purely practical grounds. Present practice at East Malling is represented by the " intermediate " trials in Table II. That is to say, plots are of two rows, each about twelve plants long. Thus pickers can work along one row and back along the other to the point of starting having gathered a convenient amount of fruit for weighing. Blocks are chosen so as to be as nearly square as possible. This investigation confirms the reasonableness of the practice and suggests no modifications of it.

Accuracy to be expected.

Taking 17·8 per cent, the median value of V in Table II, as being of general application, it follows that seven replicates would be needed for a difference of 20 per cent in the treatment means to be significant ($P = 0{\cdot}05$). That this is very different from Edgar's result is explained by the extreme uniformity of her plants in the first cropping year, which was taken as a basis for the study. Unfortunately this was an isolated example, not to be repeated in the trials of subsequent years. The only hope for the future is an improvement in experimental material, and this means a better control of strawberry diseases.

II. RECORDS FOR USE IN CALIBRATION.

Pearce and Taylor (1950) pointed out the value of estimating the potentialities of each plot of an experiment and of correcting subsequent yields by the estimate, using the analysis of covariance.

In strawberry cultural trials it is common for treatments to be applied about a year after planting, so a search has been made for suitable records to use then. It has been necessary to use data from trials in which the treatments were either inherent in the material (i.e. were different varieties or strains) or else were applied sooner than a year after planting. However, correlations based on the residual variation after allowing for block and treatment effects should show what calibration would achieve.

Crop weight.

If the plants are not de-blossomed in the first season, the crop for that year is an obvious candidate. Correlations between crop weight in the first and second years are set out for five trials in Table IV,

TABLE IV.

CORRELATION COEFFICIENT (r) BETWEEN CROP WEIGHTS IN MAIDEN YEAR AND THE FOLLOWING YEAR.

Trial no.	Plot shape.	Mean crop/plant in maiden year(gm.).	r.	Degrees of freedom.
12a*	2 × 12	54	−0·74	5
16	2 × 12	38	−0·07	50
17	4 × 23	25	+0·29	27
18	2 × 25	20	+0·30	5
19	1 × 5	18	+0·23	17

* Half of the blocks of this trial were de-blossomed in the maiden year, the others were not.

along with the mean crop per plant in the first year. None of the correlation coefficients is significantly different from zero, though they appear to increase as the one-year crops decrease. Too much must not be made of this, for there are only five trials and there are only five degrees of freedom for two of them. However, a negative correlation might well be expected if first year crops are appreciable, since the plant would put into maturing fruit resources which otherwise could be used to promote growth, to the benefit of the following year's crop. If the first year crop as a whole were small, it might yet indicate the cropping potentialities of the plant without robbing it of resources, and so give a positive correlation. However, this cannot be proved and it must be concluded that the first year crop is not a reliable record for calibration of that in the second season.

For Trial 12a the crop weights for two years after the first were available. The correlation coefficient between the total crop for these years and that in the maiden year was + 0·35. For Trial 17 the total crop for three succeeding years gave a correlation coefficient with the maiden crop of + 0·41, and this differed significantly from zero. Thus the maiden crop may be a reasonable calibrator for the crop over a number of years, though this is far from proved.

Blossom weight.

Strawberry plants are usually de-blossomed in the first year, and the results of nine trials in which this was done have been examined in the same way as the five not de-blossomed. The results are presented in Table V. The correlation coefficient was always positive, and for three trials it was

TABLE V.

CORRELATION COEFFICIENT (r) BETWEEN BLOSSOM WEIGHT IN MAIDEN YEAR AND CROP WEIGHT THE FOLLOWING YEAR.

Trial no.	Plot shape.	Mean blossom wt. per plant in maiden year (gm.).	r.	Degrees of freedom.
12b	2 × 12	7·3	+0·12	5
14	2 × 14	4·1	+0·30	19
3	2 × 12	3·9	+0·01	20
2	2 × 12	3·0	+0·53***	34
20	2 × 25	2·4	+0·16	4
5	2 × 12	2·4	+0·16	26
4	2 × 14	2·0	+0·29	20
9	2 × 12	1·8	+0·55**	27
21	4 × 23	1·3	+0·50*	14

greater than 0·5 and significantly different from zero. There is no notable relation between the correlation coefficient and the mean blossom weight per plant.

For all trials except 12b, crops for more than one year were available and correlation coefficients were computed between the blossom weight and the total crop weight for all years. They were close to the values given in Table V for all trials except 4 and 14, for which they fell to 0·06 and 0·09 respectively.

Vigour records.

Table VI gives correlations between the height and spread of the plants in the autumn after planting and the crop weight the following year for four trials; in Trial 2 the vigour records were made in the second spring after planting and are correlated with the crop weight the same year.

TABLE VI.

CORRELATION COEFFICIENTS BETWEEN VIGOUR RECORDS AND CROP WEIGHT THE FOLLOWING SUMMER, AND COEFFICIENTS OF VARIATION.

Trial no.	Plot shape.	Degrees of freedom for correlation coefficients.	Correlation coefficient with :—				Multiple R. with total height and total spread.	V.	
			Total height.	Total spread.	Number of plants.	m.		Uncorrected.	Double covariance.
2	2 × 12	34	0·84***	0·75***	0·01	0·84***	0·84***	17·9	10·1
5	2 × 12	26	0·69***	0·75***	0·55***	0·74***	0·77***	19·4	13·0
22	2 × 14	19	0·40	0·38	0·17	0·46*	0·42	24·2	23·1
23	2 × 12	24	0·61**	0·21	0·15	0·60***	0·71***	16·7	12·2
24	2 × 12	48	0·51***	0·17	0·30*	0·39**	0·57***	8·6	7·2

All correlation coefficients positive.

Correlation coefficients were worked out between the crop and the total height and total spread of all plants in the plot when measured. It will be seen that the majority of these were significantly different from zero, and the correlation with total height was the greater in four of the trials. The multiple correlation coefficient on total height and total spread was also worked out for each trial. It was significant for all the trials except 22, for which it was very near the $P = 0{\cdot}05$ point. Examination of the partial correlations suggested that it is usually better to use both the variates than to use one of them only.

Many missing plants may seriously increase variability between plots, and will also affect height and total spread. The correlations found so far are not merely due to the varying numbers of plants, for in the four trials for which the multiple correlation is significant, it is still significant when this disturbing factor is removed.* Actually the correlation between crop and number of plants is only significant for two of the trials. This is hardly surprising as there were few missing plants in any trial.

Although possibly time saving the use of a composite measure (m) of height and spread was much less effective than the use of multiple correlation.

Records were also available in May of the year of cropping for Trials 5, 22 and 24, and gave correlations with crop closely similar to those of the autumn records.

It must be noted that covariance methods can only validly be applied if the regression coefficients are the same for all treatments. For each of these trials a test was made whether the regression coefficients of crop on total height and total spread differed between strains or varieties. The differences were never significant. These tests were approximate in that the total variation within strains or varieties, without correction for block effects, was used. For Trial 22 a test was also carried out using the more complicated exact method with allowance for blocks (Carter, 1949) and this confirmed that there was no significance. Of course, regression coefficients might still differ if one treatment caused a crop failure.

Discussion.

It is evident that, in general, vigour measurements are the best of the three that have been considered. They are easily obtained. Table VI includes the coefficient of variation, V, for crop weight without correction and with a double covariance on total height and total spread, and it will be seen that the reduction is usually very worthwhile. It is therefore recommended that when treatments are to be imposed more than a year after planting, the heights and spreads in the first season should be recorded and a double covariance carried out.

Although the correlation of crop with previous vigour records is high, it is not high enough for crop records to be dispensed with and an estimate from the vigour records used instead. For three of the five trials the multiple correlation coefficient is no greater than $0{\cdot}71$, and so not more than half of the variation in crop can be represented by the vigour record.

III. THE INTERPRETATION OF SPREAD MEASUREMENTS.

Few strawberry trials in recent years have been free from disease and this factor may well influence the " vigour " as shown by height and spread. Thus if plants die, their neighbours having more space may grow larger, whereas if the plants are enfeebled the average height and spread may be mainly a record of the amount of disease rather than the " vigour " of healthy plants under a particular treatment.

To throw light on these questions, in November, 1949, a spread measurement on five variety and strain trials was supplemented by a health record. The main health categories were : O—no symptoms, A—mild virus, B—yellow-edge, C—severe crinkle. Plants with Verticillium Wilt, mite or eelworm were excluded from analyses. For Trial 12 plants were recorded as being in categories O or A, or in B or C.

Plants adjacent to missing ones.

Throughout the following the expression " a missing plant " means that the original plant was missing whether replanted or not. For Trials 16 and 25 there were no replants. For the others, even if there was a replant it was probably not large enough to offer effective competition, and if the number of missing plants is to be regarded as an index of disease the above definition is obviously necessary.

* i.e. a triple covariance on number of plants, total height and total spread gives a significant reduction in error compared with a single covariance on number of plants.

For each of Trials 6, 16, 23 and 25 there was no significant difference in the proportion of seriously diseased plants (categories B and C) between those that were adjacent to missing plants in the row and those that were not.

For each Trial, each disease category was taken separately and a test carried out whether plants of that category that were adjacent to missing plants had different mean spreads from those of the same category in the same plot that were not. Out of fifteen analyses made, the difference was significant at the $P = 0{\cdot}05$ level in only one, that for Category B plants in Trial 16, and here a plant adjacent to a missing one averaged 1·1 inches larger than one not adjacent. The average spread of all plants was 10·8 inches. This result contrasts with that obtained for hops by Amos and Hoblyn (1928).

For five other Trials, numbers 3, 5, 9, 24 and 26, spread records in other years were analysed in the same way, except that as no health record was made it was necessary to include plants of all states of health together. For Trials 24 and 26 plants adjacent to gaps were significantly *smaller* than others, but only by 1·1 and 1·2 inches respectively. For Trials 3, 5 and 9 there was no difference. Taking all the results together, it is clear that any difference in spread between plants adjacent to missing ones and the remainder will be negligible.

Relation to disease.

For Trials 6, 16, 23 and 25 the mean spread of plants of each disease category was calculated for each plot (see Table VII). For Trial 12 mean values are given for categories O and A together and for B and C together. The figures show that generally plants in categories B and C were smaller than those in O and A, as was expected. Further examination showed that this was usually because some of the

TABLE VII.

MEAN SPREADS (INCHES) IN NOVEMBER, 1949.

Trial no.	Winter of planting.	Disease category.			
		O.	A.	B.	C.
6	1945/6	17·2	16·3	14·8	11·4
23	1946/7	18·5	14/4	11·4	12·9
12	1947/8	15·0		10·4	
16	1948/9	12·6	12·5	11·3	—
25	1948/9	10·7	10·9	9·8	10·4

plants in categories B and C were much smaller than the remainder, which were about the same size as healthy plants. This may reflect the varying lengths of time for which the plants have been infected. The few plants with Verticillium Wilt were very much smaller than healthy ones because the outer leaves of such plants die, and the spread is only measured on the healthy part of the plant.

The mean spread per plant for a plot must, then, depend in part upon its health. Can it be used as a measure of that health ? As a measure of health the number of surviving plants in category O was used ; and correlation coefficients between this and the mean spread were calculated for Trials 6, 16, 23 and 25, being based on the residual variation after allowing for block and variety effects. Their values lay between $-0{\cdot}16$ and $+0{\cdot}35$, and none of them was significantly different from zero at the $P = 0{\cdot}05$ level. Nor was there ever a significant correlation between the number of surviving plants in all health categories, which is a rough measure of health if a trial has been in progress for some time, and the mean spread. This contrasts with results found for Trials 3, 5, 9, 24 and 26. For numbers 3, 24 and 26, this correlation coefficient was greater than $+0{\cdot}50$ and was significantly different from zero, once attaining the value $+0{\cdot}81$. For the Trials 5 and 9 the coefficient was $+0{\cdot}10$ and $+0{\cdot}19$. There is no apparent reason for these differences in behaviour, but at least it is certain that mean spread is not regularly a good measure of health.

Discussion.

By itself, the mean spread of all plants is not a very satisfactory record where some plants in a trial are diseased. It cannot be used as a measure of health. As disease has some effect on spread, it will not be a good measure of the size of plants growing under equal conditions of health, either. It is

therefore recommended that when spread is measured a health record should also be taken, not necessarily as detailed as that used here, but at least a division between healthy and diseased plants. The number of healthy plants and the mean spread of healthy plants would then provide measures of the two factors.

The mean spread of all healthy plants may be used without correction for effects of gaps, since plants adjacent to the gaps are apparently similar in size to the others. The mean spread of healthy plants would be based on different numbers of plants in different plots, and so its variability would not be constant. However, an investigation indicated that the plot-to-plot variability was much greater than that due to the number of plants in the plot, so there should be little error in carrying out an ordinary analysis of variance on the mean spreads. This applies only to strawberries ; with other longer lived plants, e.g. hops, the effect of gaps may be much greater.

Acknowledgements.

The author wishes to thank Dr. S. C. Pearce, Dr. W. S. Rogers and Miss D. J. Wilson for helpful discussions on this subject.

Summary.

1. The results of a uniformity trial carried out in 1934 have been re-examined ; subsequent experience suggests that the plants had unusually low variability. Plots of 24 plants, in two rows of twelve have proved useful in practice. Blocks nearly square in shape give some reduction in variability, but it is still high, about seven replicates being needed if a 20 per cent difference is to be significant at the $P = 0{\cdot}05$ level.

2. If treatments are not applied for about a year after planting, calibration using plant heights and spreads is an effective method of reducing variability in the subsequent crop. If the plants are de-blossomed in the first year the blossom weight may be of value, but this is less certain. If the plants are not de-blossomed the crop weight in the first year is of no value for calibration.

3. Spread records on the plants in five strawberry trials have been examined in relation to a health category record. Virus disease has some effect on spread, but not sufficient for the mean spread of all plants to be a good measure of health. It is recommended that spread records should normally be supplemented by health records and the mean spread of healthy plants only used as a measure of the size attainable by plants under the various treatments.

Under the conditions of these trials, plants adjacent to missing ones do not differ in spread from others in the same plots.

References

Amos, J. and Hoblyn, T. N. (1928). Manurial trials with hops. *Rep. E. Malling Res. Sta. for 1926-27, II Suppl.*, 165-71.

Carter, A. H. (1949). The estimation and comparison of residual regressions. *Biometrika*, **36**, 26-46.

Christidis, B. G. (1931). The importance of the shape of plots in field experimentation. *J. agric. Sci.*, **21**, 14-37.

——— (1939). Variability of plots of various shapes as affected by plot orientation. *Emp. J. exp. Agric.*, **7**, 330-42.

Edgar, Joyce L. (1938). Strawberry cultivation studies. II. Variability in individual plant size and cropping, with special reference to area and shape of plots for field experiments. *J. Pomol.*, **16**, 91-100.

Pearce, S. C. (1950). The interpretation of uniformity trials. *Rep. E. Malling Res. Sta. for 1949*, 91-2.

——— and Taylor, J. (1950). The purpose and design of calibration trials. *Rep. E. Malling Res. Sta. for 1949*, 83-90.

Rogers, W. S. (1931). Strawberry cultivation ; strain, time of planting and de-blossoming. *Rep. E. Malling Res. Sta. for 1928-30, II Suppl.*, 52-64.

PLANT PHYSIOLOGY

USE OF SPRAYS TO CONTROL FRUIT DROP

VI. RAIN AND THE CONTROL OF PRE-HARVEST DROP IN SUNSET APPLES

By H. W. B. BARLOW*

Introduction.

In summarizing the effect of weather conditions on the control of pre-harvest drop by growth substance sprays, Vyvyan (1946a) quotes several papers showing that such sprays are generally more effective when applied under warm than under cool conditions, and that rain falling before the spray has dried has a deleterious influence.

In 1950 an experiment was carried out to estimate the effect of two growth substance sprays on pre-harvest drop in the apple variety Sunset, but within two hours of applying the sprays heavy rain fell, and it was felt that the effectiveness of the sprays might well have been reduced. The layout of the experiment allowed an alternative plan to be adopted by which a comparison could be made between the original application, a second one, and both together, and this was put into operation.

Materials and methods.

Five-year-old trees of Sunset on M.IX were sprayed with a proprietary anti-drop spray at a concentration equivalent to 10 p.p.m. α-naphthalene-acetic acid (NAA), or with α-(2,4,5-trichlorophenoxy)-propionic acid (TCPPA) at 5 p.p.m. The first spray was applied on 29th August at 11.30 a.m. and was followed by a heavy rain shower at 1.30 p.m. A second spray was applied on 1st September at 4 p.m. (the first suitable occasion) ; some trees received each spray alone, and some both sprays. Control trees were left unsprayed. The five replicates of each treatment were arranged in randomized blocks.

Fallen fruit had been cleared from under the trees of the original layout on 29th August, but as a few additional trees had to be used for the alternative plan, and as only a few apples fell in the intervening period, the drop records were taken as from 2nd September, and collections made at intervals until picking, i.e. on 6th, 13th, 20th and 23rd September (picking).

Brown Rot was very light on this plot, and counts of sound and rotten fruits have therefore been combined in the data presented.

Weather conditions.

Table I shows the daily maximum and minimum temperatures, sunshine hours, and rainfall for a few days after each spray.

TABLE I.

Date.	Spray.	Temperature °F.		Sunshine (hours).	Rain (inches).
		Max.	Min.		
29th Aug.	First—11.30 a.m.	66	50	7·7	0·23 (Heavy shower 1.30 p.m.)
30th Aug.		68	46	2·9	0·02
31st Aug.		66	55	0·6	0·09
1st Sept.	Second—4 p.m.	68	57	3·6	0·13 (Before noon)
2nd Sept.		66	54	8·0	0·01
3rd Sept.		65	44	0	0·11

* Member of Staff of the Research Institute of Plant Physiology, Imperial College of Science and Technology.

It will be seen that the temperature and sunshine did not differ greatly in the periods following each spray, but that rain fell shortly after the first spray, with very little after the second. Moreover, it was noted at the time that the afternoon and evening after the second spray were bright and warm, and that no rain fell until 2 a.m. on 2nd September.

Results.

Table II shows the cumulative percentage drop for two periods—from the start of the experiment until three days before picking, and the whole period. Considerable drop occurred during the last three days, and the difference between the drop up to this time and the final drop provides an index of the persistence of the effect of each spray.

Fig. I shows the rate of drop for the four periods for which records were obtained, calculated according to Vyvyan (1946b). When the rates of drop are represented correctly as a series of histograms the figure is confusing, and to clarify the results the mid-points of each period have been joined by straight lines to produce the graph presented.

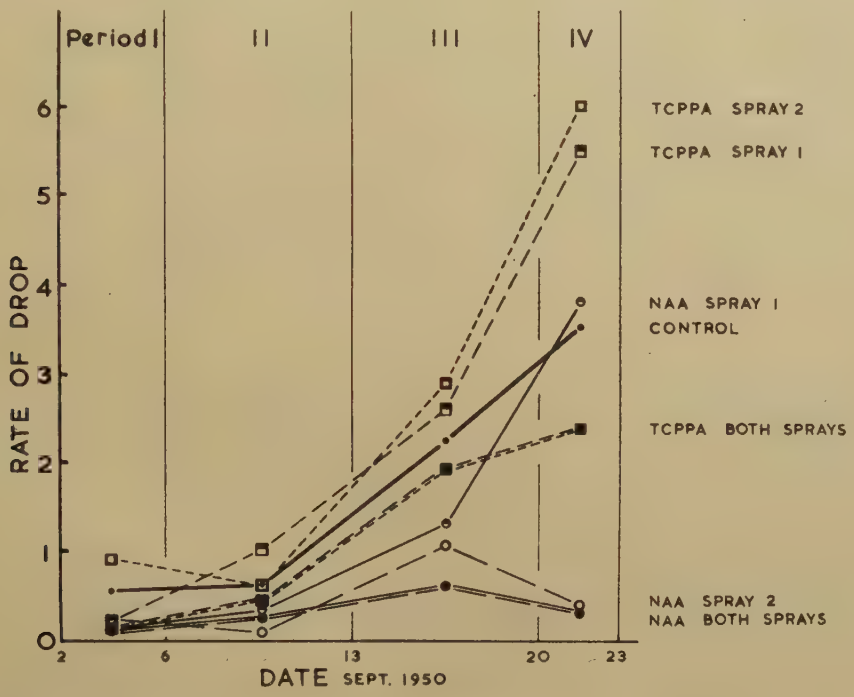


FIG. 1.

Rate of drop of Sunset apples for four periods (of 4, 7, 7 and 3 days respectively) between spraying and picking; treatments shown on right opposite each graph.

TABLE II.

CUMULATIVE PERCENTAGE DROP OF SUNSET, 1950.*

Treatment.	Period of drop.							
	2nd-20th Sept.				2nd-23rd Sept.			
	Unsprayed.	Spray.			Unsprayed.	Spray.		
		1.	2.	Both.		1.	2.	Both.
Control ..	19·6				28·1			
NAA 10 p.p.m...		10·9	8·4	6·2		22·8	9·2	7·1
TCPPA 5 p.p.m.		23·5	23·8	14·9		34·9	36·8	21·6

* The figures given are reconverted from the Bliss transformation values used in the analysis.

It is apparent from a statistical analysis of the results that TCPPA was not effective in controlling pre-harvest drop in this variety at the concentration of 5 p.p.m. used, and indeed with the single applications on either occasion there was an increase in the final drop, although the differences were not statistically significant. NAA, on the other hand, was effective when applied under suitable conditions, but rain falling within two hours of the first application seriously impaired the final effect on drop, although up till three days before picking the effect was nevertheless considerable, though failing to reach significance. This sudden wearing off of the effect is clearly shown in Fig. 1 ; in the case of the first NAA spray the rate of drop in the last three-day period rises steeply to exceed the control rate, while in the case of the second spray, either applied alone or in addition to the first, the rate was rather lower than in the preceding period.

Discussion.

Although the evidence of this experiment is not conclusive, the suggestion of an increased drop resulting from single sprays of TCPPA is interesting because this substance was tested by an intensive method in 1948, and showed considerable promise as an inhibitor of abscission when used at 20 p.p.m. on Cox's Orange Pippin. It is possible, in the light of other work using 2,4-dichlorophenoxy-acetic acid (Barlow, 1950), that these substances are alike not only in inhibiting abscission above some particular concentration, but in tending to accelerate it at lower concentrations. If 5 p.p.m. were just in the accelerating range, the two applications together might have brought the spray to the point at which there was little effect either way.

NAA has not shown any tendency to promote abscission of fruits at low concentrations, and has occasionally been effective as an inhibitor at 1 p.p.m. (Barlow, 1948).

That there was no influence of rain on the effect of TCPPA might have been due to its relative insolubility in water ; NAA in the formulation employed is water soluble.

Summary.

1. Sprays of α-naphthalene-acetic acid (NAA) at 10 p.p.m. and α-(2,4,5-trichlorophenoxy)-propionic acid (TCPPA) at 5 p.p.m. applied to Sunset apples to control pre-harvest drop were followed within two hours by heavy rain.

2. A second set of applications was not interfered with by rain, and showed that NAA controlled preharvest drop in this variety, but that the effectiveness was reduced by the rain after the first application.

3. Temperature around the time of spraying was not likely to be a factor influencing the results of this experiment.

4. TCPPA was not effective in controlling pre-harvest drop in this variety at 5 p.p.m. even when applied twice.

References

Barlow, H. W. B. (1948). Intensive experimental methods in abscission studies. *Rep. E. Malling Res. Sta for 1947*, 121-5.

——— (1950). Studies in abscission. I. Factors affecting the inhibition of abscission by synthetic growth substances. *J. exp. Bot.*, **1**, 264-81.

Vyvyan, M. C. (1946a). Fruit fall and its control by synthetic growth-substances. *Tech. Commun. imp. Bur. Hort.*, **18**.

——— (1946b). Experiments with growth substances for reduction of pre-harvest drop of fruit. *J. Pomol.*, **22**, 11-37.

USE OF SPRAYS TO CONTROL FRUIT DROP

VII. EFFECT OF SEASON AND DATE OF SPRAYING ON CONTROL OF JUNE DROP IN COX'S ORANGE PIPPIN

By M. C. VYVYAN and G. F. TROWELL

Introduction.

Marked control of June drop in Cox's Orange Pippin apple was obtained in 1946 by applying a spray of α-naphthalene-acetic acid (NAA) on 1st July (Vyvyan and Barlow, 1947) ; the crop was increased more than three-fold without any serious decrease in fruit size or quality. Considerable control was likewise obtained in 1947 by applying NAA during the third week of June. It was then shown that the NAA could be added to a routine spray of lead arsenate or of dispersible sulphur normally applied at that period, thus obviating the necessity for an additional treatment. The results of adding the NAA to a summer petroleum spray were inconclusive (Vyvyan and Barlow, 1948).

Several routine insecticide or fungicide sprays are normally applied during the period between petal-fall and the end of the June drop, each providing an opportunity for an application of NAA ; it is desirable to know to which of these the NAA should be added to obtain the best control of drop. Moreover, there are alternative sprays that may be used during this period, certain of which may tend to induce fruit or leaf-drop. It is desirable to know if the addition of NAA to such sprays will eliminate this disadvantage and thus render them safe to use. Experiments designed to throw light on these problems, and to give further information on seasonal variations in the intensity of June drop and on the effectiveness of NAA sprays, were carried out in 1948 and 1949 and are described below.

The effect of NAA applied at the end of May and at the beginning of July, 1948.

This experiment was carried out on some 520 thirteen-year-old trees of Cox's Orange Pippin on M.IX ; these included the trees used in the 1947 experiments (Vyvyan and Barlow, 1948). As the crop in 1948 was very light and variable, groups of 24 to 33 trees were used as experimental units. There were twenty such units, arranged in five blocks of four plots. All the trees received routine sprays of dispersible sulphur (" Spersul " 3½ lb. per 100 gallons) on 27th May and of lead arsenate (2 lb. per 100 gallons) on 6th July. The four experimental treatments were : (A) Control, no NAA in either spray ; (B) NAA in July spray ; (C) NAA in May spray ; and (D) NAA in both July and May sprays. A proprietary brand of NAA was used at the strength recommended by the makers.

The results are summarized in Table I. The total drop was very light and varied little from treatment to treatment. The low rate of drop may have been a seasonal effect ; more likely it was due to the lightness of the crop borne by the trees this season. The average number of fruits per tree on 27th May was only 84, and 58 of these remained on the tree until the time of picking in September.

The effect of NAA applied with lime-sulphur in June and with summer petroleum in July.

This experiment was carried out on 48 mature trees, arranged in three rows of sixteen. Two of the rows were used in the 1946 experiment on June drop but, as alternate trees had been grubbed, no guard trees were required between treatments. There were sixteen different treatments in all, comprising all combinations of four treatments applied on 14th June and of four applied on 9th July. The four treatments in June were : no spray ; lime-sulphur alone ; NAA alone ; lime-sulphur plus NAA. The four treatments in July were : no spray ; summer petroleum alone ; NAA alone ; summer petroleum plus NAA (see Table II). The NAA was a proprietary brand, used at the recommended strength ; the lime-sulphur was used at the strength of ¾ gallon per 100 gallons and the summer petroleum 1 per cent. There was a light shower of rain thirty minutes after the completion of the July spraying which may have reduced its effectiveness (Barlow, 1951). The ground was cleared under the trees at the time of the first spray and subsequent drops were collected and counted on 29th June, 12th, 19th and 23rd July, and on 3rd, 16th and 30th August and on 14th September. The fruits were picked on 7th October and the final collection of drops, on 9th October, included those knocked off during picking. Owing to an error, the ground was cultivated once between 29th June and 12th July and a number of the fruits that dropped during that period were thus lost. The number of fruits on each tree on 12th July can be determined accurately by summing subsequent drops and picked fruits. The initial numbers on 14th June can only be estimated approximately, ignoring the loss during cultivation ; errors introduced by these losses, however, would be likely to diminish rather than increase differences between the values for the various treatments.

TABLE I.

EFFECT OF ADDING NAA TO A DISPERSIBLE SULPHUR SPRAY IN MAY AND TO A LEAD ARSENATE SPRAY IN JULY, 1948. TREES BEARING A VERY LIGHT CROP.

Treatment.	First spray. Dispersible sulphur applied, 27th May.	Second spray. Lead arsenate applied, 6th July.	Percentage dropped. Up to 7th July.	Percentage dropped. 7th July till 18th August.	Percentage dropped. After 18th August.*	Percentage picked 20th-21st September.
A	—	—	15·3	4·4	10·1	70·2
B	—	+ NAA	18·2	3·3	13·8	64·7
C	+ NAA	—	15·5	3·2	8·4	72·9
D	+ NAA	+ NAA	11·9	2·1	10·2	75·8
	Mean values					
A and B	—		16·7	3·9	11·9	67·5
C and D	+ NAA		13·7	2·6	9·3	74·4
A and C		—	15·4	3·8	9·2	71·6
B and D		+ NAA	15·0	2·7	12·0	70·3
	Sig. diff. (P = 0·05)		*5·7*	*1·1*	*2·9*	*9·2*

* Includes fruits knocked off during picking. The brackets combine values whose difference is insignificant.

The results are summarized in Table II, which gives the mean values of the numbers of fruits picked per tree. The differences are not significant, nor were they when expressed as percentages of the estimated number of fruits present on the trees on 15th June or as percentages of those present on 12th July.

TABLE II.

NUMBERS OF SOUND FRUITS PICKED PER TREE ON 7TH OCTOBER, 1948.

First spray (14th June).	Second spray (9th July). Unsprayed.	Summer petroleum.	NAA.	Summer petroleum + NAA.	Mean	*Sig. diff.*
Unsprayed ..	132	357	415	424	332	
Lime-sulphur ..	221	323	225	261	258	
NAA	540	331	329	450	413	*153*
Lime-sulphur + NAA ..	311	293	366	345	329	
Mean	301	326	334	370	333	
Sig. diff. ..		*153*				

It was already known that there are marked seasonal variations in the severity of the drop occasionally induced by lime-sulphur and by summer petroleum sprays and also in the controlling influence of NAA sprays (Vyvyan, 1946b). On this occasion neither lime-sulphur nor summer petroleum increased the drop, nor did NAA reduce it. The results of the experiments are therefore inconclusive and further work on mixtures of NAA with lime-sulphur and summer petroleum sprays will be required before their usefulness can be determined.

Effect of NAA applied on different dates in 1949.

In order to obtain information on the best time for applying NAA for control of June drop, the effect of adding NAA to routine fungicide and insecticide sprays applied on various dates was examined

in 1949. Four such sprays were involved ; dispersible sulphur plus nicotine applied on 11th May, dispersible sulphur plus derris on 2nd June, and two sprays of lead arsenate plus derris, applied on 20th June and 18th July respectively. The effect of substituting parathion for the second dispersible sulphur spray was also examined. There were sixteen different treatments in all ; they were applied at random to plots in each of ten blocks, each plot consisting of three adjacent trees. These 480 trees were the same as those used in the 1947 experiments and in the 1948 experiment described above.

The treatments are shown in Table III. First, a general control, where the trees received the four routine sprays without any NAA (1). Next, where NAA was added to all four sprays (2). In the May spray the treatments were varied in three ways—some trees were left unsprayed (3), some received NAA alone (4), and others NAA mixed with dispersible sulphur (5). Similar variations in treatment were made on the other three occasions (6, 8 and 9, 11-13, 14-16). In addition, on the second occasion, 2nd June, two further treatments were included—parathion alone (7) and parathion plus NAA (10).

TABLE III.

CUMULATIVE PERCENTAGE DROPS, 1949.

Serial no.	Treatment.				Percentage drop up to :				
	11th May.	2nd June.	20th June.	18th July.	21st June.	19th July.	8th Aug.	30th Aug.	22nd Sept.
1	**Dn –**	**Dd –**	**Ld –**	**Ld –**	28	43	46	49	58
2	**Dn N**	**Dd N**	**Ld N**	**Ld N**	3	12	16	20	41
3	– – –	**Dd –**	**Ld –**	Ld –	28	44	47	52	59
4	– – **N**	Dd –	Ld –	Ld –	10	36	41	46	61
5	**Dn N**	Dd –	Ld –	Ld –	9	39	43	50	64
6	Dn –	– – –	Ld –	Ld –	15	34	37	41	52
7	Dn –	**E – –**	Ld –	Ld –	30	43	45	47	54
8	Dn –	– – **N**	Ld –	Ld –	5	21	23	28	43
9	Dn –	**Dd N**	Ld –	Ld –	5	25	27	32	43
10	Dn –	**E – N**	Ld –	Ld –	9	25	27	30	40
11	Dn –	Dd –	– – –	Ld –	25	41	46	53	65
12	Dn –	Dd –	– – **N**	Ld –	22	34	37	42	57
13	Dn –	Dd –	**Ld N**	Ld –	23	34	36	39	49
14	Dn –	Dd –	Ld –	– – –	25	37	42	48	60
15	Dn –	Dd –	Ld –	– – **N**	22	37	38	42	54
16	Dn –	Dd –	Ld –	**Ld N**	23	37	38	41	51
	Sig. diff. ($P = 0{\cdot}05$)				5·0	6·8	6·8	6·8	

Notation. D = Dispersible sulphur ; n = nicotine ; d = derris ; E = parathion ; L = lead arsenate ; N = α-naphthalene-acetic acid. Differential treatments in each group are indicated by heavy type.

It was not found possible to record the numerous blossoms and small fruits that fell in May, but the ground under the trees was cleared on 3rd June and subsequent drops were collected and counted on 21st June, 19th July, 8th August, 30th August, and on 22nd September. This final count included the fruits knocked off during picking. The picked fruits were likewise counted and were sorted into " sound " and " unsound ".

The results are summarized in Tables III, IV and V. The total number of fruits dropped up to successive dates are shown in Table III, where they are expressed as percentages of those present on the trees on 3rd June. Table IV shows the mean rates of dropping during the successive periods ; these have been worked out by the logarithmic method described by Vyvyan (1946a). The relative numbers of sound fruits picked are shown in Table V, where the values for the sixteen treatments are arranged in order of increasing magnitude and those that do not differ significantly are bracketed. Values for total numbers picked, sound and unsound, are not given as they are of less interest, but they can be readily obtained from those for total drops in the last column of Table III. For example, the value for total percentage drop for Treatment 1 was 57·8 and the total percentage picked was therefore 42·2.

The use of percentages, based on the numbers present on 3rd June, is not strictly legitimate in the case of treatments 2, 3, 4 and 5, where the differential treatments were applied on 11th May and may have influenced the numbers present on the tree on 3rd June. The values for the numbers of fruits picked are not subject to this disqualification. These values, though not given here, were compared

Table IV.

Mean percentage rate of drop, period by period, 1949.

Serial no.	Treatment.				Rate of drop.				
	11th May.	2nd June.	20th June.	18th July.	3rd June to 21st June.	21st June to 19th July.	19th July to 8th Aug.	8th Aug. to 30th Aug.	30th Aug. to 22nd Sept.
1	**Dn –**	**Dd –**	**Ld –**	**Ld –**	1·85	0·87	0·21	0·32	0·83
2	**Dn N**	**Dd N**	**Ld N**	**Ld N**	0·17	0·36	0·19	0·23	1·25
3	– – –	Dd –	Ld –	Ld –	1·88	0·93	0·26	0·40	0·84
4	– – **N**	Dd –	Ld –	Ld –	0·61	1·22	0·41	0·44	1·40
5	**Dn N**	Dd –	Ld –	Ld –	0·47	1·45	0·40	0·54	1·48
6	Dn –	– – –	Ld –	Ld –	0·95	0·89	0·20	0·36	0·83
7	Dn –	**E** – –	Ld –	Ld –	2·00	0·80	0·15	0·17	0·63
8	Dn –	– – **N**	Ld –	Ld –	0·29	0·65	0·15	0·34	0·97
9	Dn –	**Dd N**	Ld –	Ld –	0·30	0·83	0·19	0·29	0·75
10	Dn –	**E – N**	Ld –	Ld –	0·55	0·71	0·18	0·15	0·65
11	Dn –	Dd –	– – –	Ld –	1·63	0·89	0·40	0·67	1·29
12	Dn –	Dd –	– – **N**	Ld –	1·43	0·57	0·23	0·45	1·30
13	Dn –	Dd –	**Ld N**	Ld –	1·49	0·54	0·17	0·23	0·80
14	Dn –	Dd –	Ld –	– – –	1·60	0·61	0·44	0·55	1·23
15	Dn –	Dd –	Ld –	– – **N**	1·41	0·74	0·13	0·27	1·04
16	Dn –	Dd –	Ld –	**Ld N**	1·43	0·73	0·15	0·21	0·77
	Sig. diff. ($P = 0·05$)				*0·38*	*0·25*	*0·13*	*0·12*	*0·33*

Notation. D = Dispersible sulphur; n = nicotine; d = derris; E = parathion; L = lead arsenate; N = α-naphthalene-acetic acid. Differential treatments in each group are indicated by heavy type.

with those for the percentages. The only considerable difference in the relative positions of the values for these four treatments was for treatment 2, trees that received NAA on all four occasions. In Table V this value is relatively high, but on the basis of actual numbers it was the third lowest and only slightly greater than those for treatments 4 and 5.

The values in Table V show that the control trees, which receive the full spray programme without the addition of any NAA, occupy the central position in the table, whether the second spray was dispersible sulphur (1) or parathion (7). Trees that received NAA on 11th May (4, 5) and those unsprayed on 20th June (11), bore significantly smaller crops than the controls. Trees receiving NAA on 2nd June (8, 9, 10), bore significantly larger crops. The values for trees sprayed with NAA on 20th June (12, 13) and 18th July (15, 16) were not significantly different from the controls, but in each case the value for NAA applied alone is significantly less than that for NAA added to the lead arsenate.

The values in Tables III and IV indicate the manner in which the differences in crop were brought about. Omission of the first dispersible sulphur spray (3) had no effect on drop, while omission of the second (6) significantly reduced the drop during the period up to 21st June. Omission of lead arsenate, whether NAA was applied (12, 15) or not (11, 14), resulted in an increase in the rate of drop during the last period before picking.

Trees sprayed with NAA on 11th May (4, 5) showed a reduced rate of drop up to 21st June, followed by an increased rate up till picking time. It was noticed in May and June that the leaves on trees sprayed with NAA on that date looked slightly wilted and that many small fruits, which failed to grow, were retained on the trusses. Addition of NAA to dispersible sulphur (9) or parathion (10) on 2nd June, resulted in an initial reduction in drop and an increase in crop. Addition of NAA to lead arsenate sprays on 20th June and 18th July (13 and 16) had little effect. Addition of NAA to all four sprays (2) resulted in a great reduction in the rate of drop up to the time of the fourth spray which apparently had no effect. During September the rate of drop was greater than in the controls.

It is rather surprising that NAA sprays applied on 20th June had little effect, for sprays applied at about this date were very effective in 1947. The 1949 season, however, was an early one, and the fruits may have been more mature at that period.

The NAA spray on 2nd June was relatively effective. This evidence of seasonal variation suggests that it would probably be a wise precaution, where control of June drop is required, to apply NAA,

TABLE V.

RELATIVE CROPS. NUMBERS OF SOUND FRUITS PICKED PER TREE, EXPRESSED AS PERCENTAGES OF TOTAL NUMBERS PRESENT ON 3RD JUNE, 1949.

Serial no.	Treatment.				Relative crop, arranged in order of magnitude.
	11th May.	2nd June.	20th June.	18th July.	
5	Dn N	Dd –	Ld –	Ld –	22·5
4	– – N	Dd –	Ld –	Ld –	23·4
11	Dn –	Dd –	– – –	Ld –	23·5
14	Dn –	Dd –	Ld –	– – –	26·8
15	Dn –	Dd –	Ld –	– – N	26·9
12	Dn –	Dd –	– – N	Ld –	28·3
3	– – –	Dd –	Ld –	Ld –	31·2
1	Dn –	Dd –	Ld –	Ld –	32·2
7	Dn –	E – –	Ld –	Ld –	34·0
16	Dn –	Dd –	Ld –	Ld N	35·9
6	Dn –	– – –	Ld –	Ld –	37·4
13	Dn –	Dd –	Ld N	Ld –	38·4
2	Dn N	Dd N	Ld N	Ld N	38·8
9	Dn –	Dd N	Ld –	Ld –	44·2
8	Dn –	– – N	Ld –	Ld –	44·6
10	Dn –	E – N	Ld –	Ld –	45·5
	Sig. diff. ($P = 0·05$)				6·3

Notation. D = Dispersible sulphur; n = nicotine; d = derris; E = parathion; L = lead arsenate N = α-naphthalene-acetic acid.

either alone or in a routine protective spray, on two occasions; one at the beginning and the other towards the end of June. Applications of NAA towards the beginning of May appear to be harmful and should be avoided; applications late in July would appear to be of little value.

Summary.

1. Experiments in 1948 and 1949 gave further evidence of seasonal variation in the intensity of June drop and in the effectiveness of NAA (naphthalene-acetic acid) sprays for its control.

2. Trees bearing a very light crop showed little June drop in 1948 and no response to one or two applications of NAA.

3. Sprays of lime-sulphur in mid-June and of summer petroleum in early July induced no additional drop and NAA applied on one or both occasions had no appreciable effect.

4. In 1949 the date of applying NAA was found to be important. The crop was considerably increased by NAA sprays applied on 2nd June. Applications on 20th June and 18th July had little effect while applications on 11th May were harmful and reduced the crop. Applications repeated on all four dates increased the crop, but less than a single spray applied on 2nd June alone. Better results were obtained by adding the NAA to dispersible sulphur, parathion and lead arsenate sprays than from applying it alone.

5. In view of the seasonal differences in response to NAA sprays applied in late June, an additional application in a routine protective spray at the beginning of June is suggested.

REFERENCES

BARLOW, H. W. B. (1951). Use of sprays to control fruit drop. VI. Rain and the control of pre-harvest drop in Sunset apples. *Rep. E. Malling Res. Sta. for 1950*, 108-9.

VYVYAN, M. C. (1946a). Experiments with growth substance sprays for reduction of pre-harvest drop of fruit. *J. Pomol.*, **22**, 11-37.

——— (1946b). Fruit fall and its control by synthetic growth substances. *Tech. Commun. imp. Bur. Hort.*, **18**.

——— and BARLOW, H. W. B. (1947). Use of sprays to control fruit drop, especially that of young fruit of Cox's Orange Pippin. *Rep. E. Malling Res. Sta. for 1946*, 83-7.

——— (1948). Use of sprays to control fruit drop. II. Effect of adding naphthalene-acetic acid (NAA) to a routine June spray. *Rep. E. Malling Res. Sta. for 1947*, 101-7.

ASPECTS OF ROOTSTOCK PROPAGATION

II. THE DEVELOPMENT OF THE CONCENTRATED DIP METHOD OF TREATING HARDWOOD CUTTINGS WITH GROWTH SUBSTANCES

By E. S. J. HATCHER* and R. J. GARNER

Introduction.

In an earlier paper (Hatcher and Garner, 1948) an account was given of the manner in which growth substances were being used in the propagation of fruit tree rootstocks by hardwood cuttings. This stressed the need for a standard treatment for systematic use in the experimental studies, and indicated that indole-3-butyric acid, applied by the alcoholic dip method, had been adopted. But while the dip method has been in use since 1945-6, it was necessary to determine by a series of concentration experiments the optimal dip strength for the rootstock varieties under investigation, particularly the rootstocks Myrobalan B and Crab C. As a result of three years' work it has been found practicable to work with a single growth substance treatment, namely 0·5 mg. indole-3-butyric acid per ml. 50 per cent. alcohol equivalent to a concentration of 500 parts per million. The experiments leading to this conclusion are described in the present paper.

In design and execution all the experiments followed the pattern described in detail in the first paper of this series dealing with Myrobalan B (Hatcher and Garner, 1949). It will therefore suffice to record here details important in the interpretation of the data. The two rootstocks will be considered separately before passing to a brief discussion of the results.

Experiments with Myrobalan B.

The study of the influence of planting time on the establishment and growth of hardwood cuttings of this plum rootstock, with and without dip treatment of indole-3-butyric acid, at a concentration of 5 mg. per ml. 50 per cent alcoholic solution, showed such treatment to be deleterious (Hatcher and Garner, 1949). This was so whenever the dip was applied throughout the seven months September, 1945, to March, 1946, as shown by a marked reduction in the number of established cuttings. The effect was particularly noteworthy in September before the onset of full winter dormancy, and again in March when growth recommenced. Furthermore, the appearance of the treated cuttings in the summer following planting provided a better indication of the proportion finally rooting than was the case with untreated cuttings. This suggests that the treatment stimulated more rapid physiological development irrespective of whether or not the concentration of growth substance was toxic.

The concentration of growth substance used for dip treatment in other experiments forming part of the wider investigations upon propagation methods at East Malling was accordingly reduced to 2 mg. per ml. in the following year, 1946-7. At the same time an experiment was carried out in which basal cuttings from hedge shoots of Myrobalan B were treated with dips having concentrations of 0, 0·5, 1, 1·5 and 2 mg. per ml., on each of four occasions during the winter, 17th October, 22nd November, 18th January and 2nd April. The results are given in graphical form in Figs. 1 and 2. It is apparent that the effect of concentration of dip cannot be considered independent of the season at which the cuttings are taken, but in general the two weaker dips significantly increased the percentage rooted compared with the controls, whereas the two stronger dips showed a significant opposite effect.

Considering the strong interaction ($P < 0{\cdot}01$) between dip concentration and the time of treatment and planting, it will be noted that in the October series stimulation by 0·5 and 1 mg. per ml. was marked, and the stronger dips were not adverse relative to controls. In the November series, untreated cuttings showed optimal rooting power and there was a steady decline in percentage established with increasing concentration of dip. In January, apart from an adverse effect of the most concentrated dip, little effect on rooting was apparent. The April series showed considerable increase in establishment using dips of 0·5 and 1, but marked deleterious effects of 1·5 and 2 mg. per ml.

The stimulating effect on rooting is reflected by the amount of shoot growth, the longest primary shoot being used as a growth index. A progressive falling-off in growth in the later series is to be noted (cf. Hatcher and Garner, 1949), but at all times growth substance dip treatment caused an increase which was significant. Using dips of 0·5, 1 and 1·5 mg. per ml., approximately similar

* Member of staff of the Research Institute of Plant Physiology, Imperial College of Science and Technology.

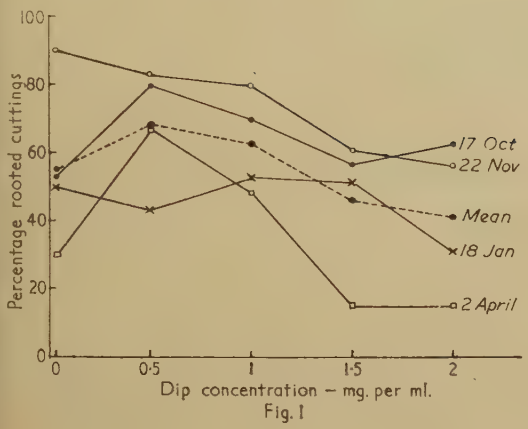


Fig. 1

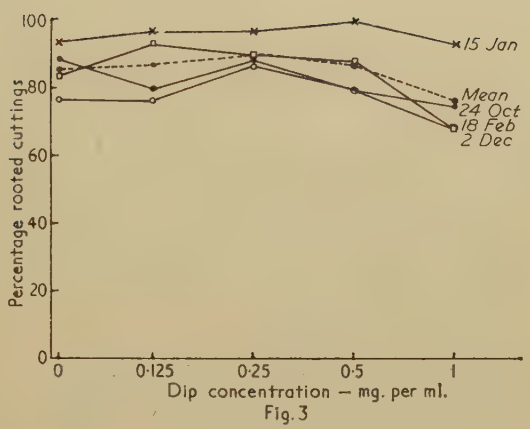


Fig. 3

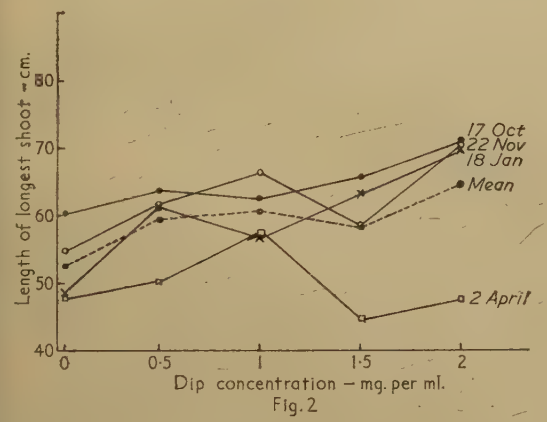


Fig. 2

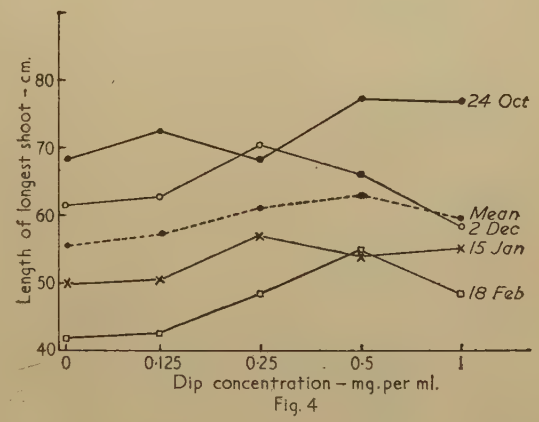


Fig. 4

Fig. 1. The effect of growth substance dips of varying concentration on the rooting of Myrobalan B cuttings in 1946-7.

Fig. 2. The effect of growth substance dips of varying concentration on the shoot growth of Myrobalan B cuttings in 1946-7.

Fig. 3. The effect of growth substance dips of varying concentration on the rooting of Myrobalan B cuttings in 1947-8.

Fig. 4. The effect of growth substance dips of varying concentration on the shoot growth of Myrobalan B cuttings in 1947-8.

growth values were observed, whereas the most concentrated dip gave a somewhat higher mean value. It is quite clear that a reduction in establishment, due to the use of a more concentrated dip, is not accompanied by a reduction in the shoot growth of the survivors, but rather the reverse.

On the basis of the 1946-7 trial the concentration of the standard dip for use in the 1947-8 season was reduced from 2 mg. per ml. to 0·5 mg. per ml. In the same season a further range of concentrations, 0, 0·125, 0·25, 0·5 and 1 mg. per ml., was investigated in a trial with similar cuttings. The experiment was again repeated four times during the dormant season, 24th October, 2nd December, 15th January and 18th February, a rather more restricted time range. The final percentage establishments and the mean lengths of the longest primary shoot are shown in Figs. 3 and 4.

This was a season when remarkably good establishments were obtained at all times of planting, so that there was less latitude for improvement by growth substance treatment. Nevertheless, though little effect of the lowest concentration was apparent, dips of 0·25 and 0·5 mg. per ml. were advantageous. This is supported by the growth data. Shoot growth manifested a progressive diminution with later dates of treatment with, in general, optimal improvement by growth substance at the concentration 0·5 mg. per ml.

In subsequent seasons 0·5 mg. indole-3-butyric acid per ml. 50 per cent alcohol has been used as the standard concentration for growth substance dips.

Experiments with Crab C.

With this rootstock a comparison was made in 1945-6 of the dip method and the older solution method, in which the cutting is stood for 20-24 hours in a dilute aqueous solution. Basal cuttings from one-year bedded stocks were prepared and treated on three occasions, 6th November, 23rd January, and 1st April. The dips used were at the concentrations of 0, 2·5 and 5 mg. indole-3-butyric acid per ml., the solution treatment at 0, 15 and 30 mg. per litre. The results are illustrated in Figs. 5, 6 and 7.

The cuttings treated in November responded differently to solution and dip treatments, growth substance in the former case reducing the percentage rooted, in the latter increasing the percentage rooted (Fig. 5). In the spring, at bud burst, exactly the reverse effect was observed, this time the solution technique being beneficial. In both the spring and winter series, alcohol alone gave consistently higher rooting percentages than water alone, evidence of the bad effect of soaking for a long period in water, even though this may be more than counteracted by growth substance. Winter cuttings showed little evidence of improved establishment rate following treatment.

There was a definite stimulating effect of growth substance on shoot growth in each time-series (Fig. 6) again showing that a toxic concentration does not impair the growth of any cutting which succeeds in rooting after treatment.

The number of cuttings which, while unrooted, were still alive at the end of the experiment (Fig. 7) was small in the case of those planted in the autumn or winter, but numerous in the spring series. There was a progressive decline with increasing concentration of growth substance, however applied, in the latter series.

This experiment demonstrated the better rooting following dip treatment in the autumn, irrespective of concentration, but showed that the dip strengths used, 2·5 and 5 mg. per ml., were too high for spring application. It may be noted that Crab C is a shy-rooter, and the degree of rooting in the untreated controls was unusually high (Fig. 5).

In the two subsequent seasons Crab C concentration trials were conducted in parallel with those already described for Myrobalan B. Basal cuttings were taken from shoots of the same, though progressively older, parent plants as before, and Table I is composite showing percentage rooting, not only for the 1946-7 and 1947-8 experiments, but, as a comparison, the dip values from the 1945-6 experiment also.

In Fig. 8 the 1946-7 values are plotted and these reveal that with October planting significant increases in the number of rooted cuttings occurred at all dip strengths, from 0·5 to 2 mg., with no definite effect of concentration. Cuttings planted at the end of November, however, rooted poorly, but with January planting a moderate increase was obtained at 1 and 1·5 mg. per ml. The spring cuttings were planted very late, at the end of April, and all died.

Results with the lower concentration dip range of the 1947-8 trial show maximum increased rooting at 0·5 mg. per ml. for October planting, but absence of response at all other occasions.

With autumn planting no deleterious effects have been observed over the whole range of dip treatments up to 5 mg. indole-3-butyric acid per ml. 50 per cent alcohol, though with spring planting these have occurred. On the other hand autumn treatment with as low a concentration as 0·5 mg. per ml. gave as satisfactory results as higher strengths ; accordingly it was decided to adopt this strength for general use on both apple and plum.

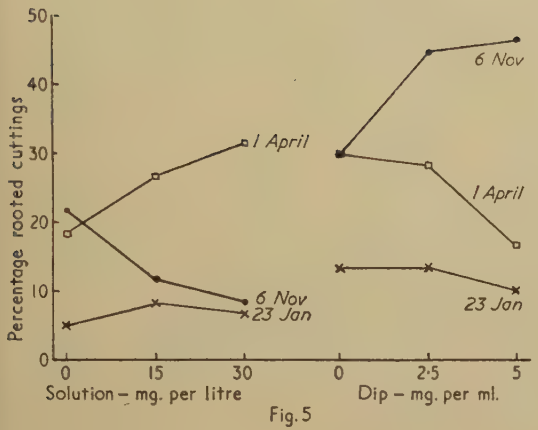


Fig. 5

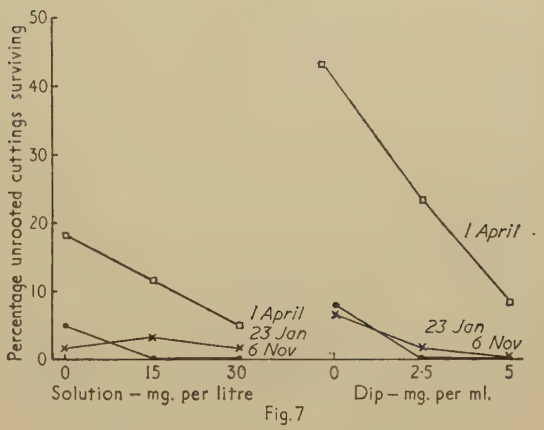


Fig. 7

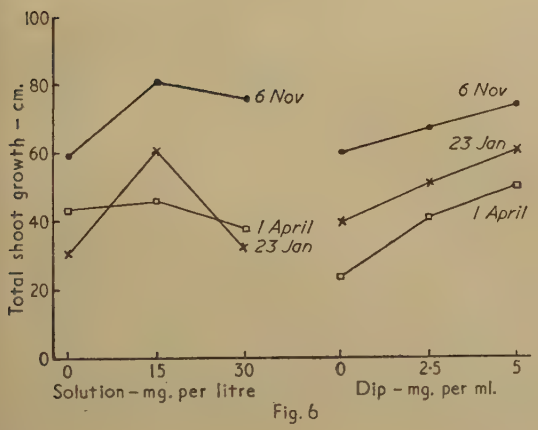


Fig. 6

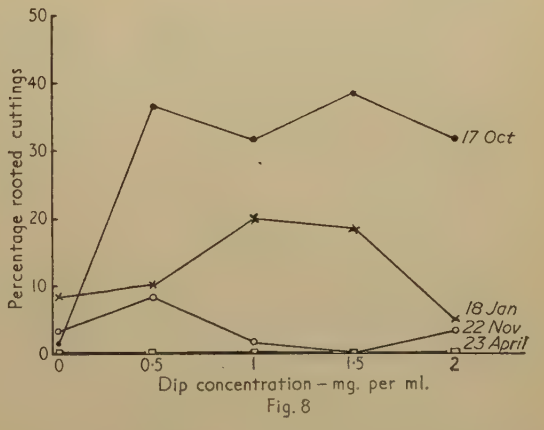


Fig. 8

Fig. 5. Comparative effects of solution and dip growth substance treatments on the rooting of Crab C cuttings in 1945-6.

Fig. 6. Comparative effects of solution and dip growth substance treatments on the shoot growth of Crab C cuttings 1945-6.

Fig. 7. Comparative effects of solution and dip growth substance treatments on the survival of unrooted Crab C cuttings in 1945-6.

Fig. 8. The effect of growth substance dips of varying concentration on the rooting of Crab C cuttings in 1946-7.

Table I.

Crab C. Basal bedded-stock cuttings.

Summary of rooting performance over a three year period—percentage of rooted cuttings.

Year.	Date of planting.	Concentration of dip : mg. indole-3-butyric acid per ml. 50 per cent alcohol.								
		0	0·125	0·25	0·5	1·0	1·5	2·0	2·5	5·0
1945-6	6th Nov.	30·0	—	—	—	—	—	—	45·0	46·7
1946-7	17th Oct.	1·7	—	—	36·7	31·7	38·3	31·7	—	—
1947-8	23rd Oct.	5·0	8·3	15·0	16·7	11·7	—	—	—	—
1946-7	22nd Nov.	3·3	—	—	8·3	1·7	0·0	3·3	—	—
1947-8	1st Dec.	0·0	1·7	1·7	0·0	0·0	—	—	—	—
1945-6	23rd Jan.	13·3	—	—	—	—	—	—	13·3	10·0
1946-7	18th Jan.	8·3	—	—	10·0	20·0	18·3	5·0	—	—
1947-8	15th Jan.	10·0	6·7	5·0	8·3	10·0	—	—	—	—
1945-6	1st April	30·0	—	—	—	—	—	—	28·3	16·7
1946-7	23rd April	0·0	—	—	0·0	0·0	0·0	0·0	—	—
1947-8	19th March	6·7	5·0	3·3	6·7	8·3	—	—	—	—

Discussion.

The simple process of momentarily dipping a cutting in an alcoholic solution of growth substance, assuming an effectiveness comparable with that obtained with the solution method, has everything to commend it from a practical point of view. With the hardwood stem cutting taken and treated as dormancy approaches in the autumn, the dip method has in fact surpassed the older solution method in its stimulating effect. Uptake from weak solutions is, of course, influenced by external conditions at the time of treatment, while the dip method is relatively independent, and consequently much more reliable. In this respect it is superior to the powder or dust method also, which although expeditious is apt to result in uneven dosage.

Application of dip treatment to a cutting in spring, when renewal of metabolic activity marks the end of dormancy, requires rather more caution, and certainly the toxic concentration is lower. Furthermore, while it may be found that at this time cuttings respond well to the uptake of growth substance by the solution method, experience with the standard indole-3-butyric acid dip of 0·5 mg. per ml. has shown that the latter technique is quite effective in the spring both with plum and apple.

Another advantage of the dip method is the avoidance of water soaking, which is far from desirable. While the presence of growth substance in solution may mask the unfavourable effect of soaking, and while water soaking may be advantageous in the case of wilted or dessicated material, with good propagating practice the replacement of long soaking by instantaneous dipping is a distinct improvement.

There is a wider margin of safety with the dip technique, the optimal concentration normally lying well below the toxic level. But just as the apple will tolerate a much stronger growth substance solution than the plum, so it requires a stronger dip to injure it, and the 5 mg. per ml. dip, which was so injurious to plum whenever applied, was not harmful to apple applied in autumn, the normal time for hardwood cuttings. The standard 0·5 mg. per ml. dip of indole-butyric acid has proved to be one suitable for general use with fruit-tree rootstocks, in the sense that it combines considerable safety with marked stimulation of rooting. It would be rash, however, to maintain that it always provided maximum stimulation, which the results described strongly suggest to be dependent upon the physiological state of the cutting, especially in relation to dormancy.

Acknowledgements.

The authors wish to thank the Statistical Section for designing the experiments and Miss C. P. Nicoll and members of the recording staff for taking growth and other records.

Summary.

1. Experiments to determine optimal concentrations of alcoholic dip treatment with indole-3-butyric acid for rootstock varieties have been undertaken over a period of three seasons.

2. With Myrobalan B plum it was found that the best concentration was 0·5 mg. per ml.; sub-optimal and eventually damaging effects being obtained with dips exceeding 1 mg. per ml.

3. With Crab C apple, while autumn cuttings responded without damage to a dip of 5 mg. per ml., yet the full rooting response to growth substance was obtained at one-tenth this strength.

4. The concentration of dip selected was 0·5 mg. per ml. for both apple and plum.

5. The merits of solution and dip methods for applying growth substance are briefly discussed, and preference for the latter is explained.

References

Hatcher, E. S. J. (1949). The use of growth-promoting substances in the vegetative propagation of plants. *Ann. appl. Biol.*, **36**, 562-6.

——— and Garner, R. J. (1948). Growth substances in their relation to hardwood stem cuttings of fruit tree rootstocks. *Rep. E. Malling Res. Sta. for 1947*, 117-20.

——— ——— (1949). Aspects of rootstock propagation. I. The influence of date of planting on the establishment and growth of Myrobalan B plum hardwood cuttings. *Rep. E. Malling Res. Sta. for 1948*, 92-8.

BIOCHEMISTRY

A NEW AND RAPID METHOD FOR ESTIMATING SMALL QUANTITIES OF CALCIUM IN PLANT MATERIAL

A PRELIMINARY NOTE

By A. C. MASON

The determination of calcium in plant material is usually based on the precipitation of calcium oxalate. The disadvantages of such methods are that they are slow and inaccuracies arise when determining small quantities, of the order of 0·1 mg. of calcium, due to solubility of the precipitate in water and consequent washing difficulties (Mason, 1950) and to interference by magnesium. Various modifications of the standard method have been suggested (Ingols and Murray, 1949, Sobel and Kaye, 1940, Tore Holth, 1949) but in the author's view they do not offer any real solution of the difficulties. The method described by Klement (1948) for the estimation of quantities of the order of 1 mg. of calcium, using picrolonic acid, is not sufficiently sensitive.

Mr. R. C. Fawcett drew the author's attention to the fact that ethylenediamine tetra-acetic acid (EDTA) is used in water hardness testing (Schwarzenbach, Biedemann and Bangerter, 1946) and suggested that it might be adapted for the estimation of calcium and magnesium.

The estimation depends on the fact that calcium forms a compound with murexide (ammonium purpurate) which is broken down in the presence of ethylenediamine tetra-acetic acid forming a more stable calcium compound of the latter and liberating the brilliant purple coloured free murexide. The ethylenediamine tetra-acetic acid combines stoichiometrically with calcium and the murexide acts as an indicator for titration (Schwarzenbach and Ackermann, 1947, Schwarzenbach, Biedemann and Bangerter, 1946). The reaction is reversible.

In a similar way calcium and magnesium may be estimated together if Eriochrome Black is used instead of murexide (Biedemann and Schwarzenbach, 1948). Attempts were made to estimate magnesium by the difference in titre of EDTA when Eriochrome Black and murexide respectively were used as indicators. On account of the fact that the concentration of magnesium in plant material is normally about a tenth that of calcium the estimation was far from precise.

Briefly the procedure for estimating calcium is to add an excess of EDTA solution from a micro-pipette to 0·1 ml. of the plant ash solution and after stirring and allowing to stand 5 to 10 minutes the excess EDTA is back titrated with standard calcium solution using murexide as indicator.

Limited experience suggests that the method is as accurate and precise as the standard methods and is suitable for the estimation of 0·1 to 0·2 mg. of calcium. The method will be published elsewhere after further experience.

Summary.

A brief description is given of a method for estimating calcium. An excess of ethylenediamine tetra-acetic acid is added and back titrated with a standard calcium solution, murexide being used as indicator.

References

Biedemann, W., and Schwarzenbach, G. (1948). The "complexometric" titration of alkaline earths and some other metals with Eriochrome Black. *Chimia* (*Switz.*), **2**, 56-61.

Ingols, R. S., and Murray, P. E. (1949). Urea hydrolysis for precipitating calcium oxalate. *Anal. Chem.*, **21**, 525-7.

Klement, R. (1948). Schnelle und einfache bestimmung kleiner mengen calcium. *Zeit. Anal. Chim.*, **128**, 431-5.

Mason, A. C. (1950). The estimation of phosphorus, potassium, calcium, magnesium, iron, manganese and nitrogen in plant material. *Rep. E. Malling Res. Sta. for 1949*, 111-15.

Schwarzenbach, G., and Ackermann, H. (1947). Komplexone V. Die Äthylendiamin-tetraessigsäure. *Helv. Chim. Acta.*, **30**, 1798-1804.

———, Biedemann, W., and Bangerter, F. (1946). Komplexone VI. Neue einfache Titriermethoden zur Bestimmung der Wasserhärte. *Helv. Chim. Acta.*, **29**, 811-18.

Sobel, A. E. and Kaye, T. A. (1940). Estimation of submicro quantities of calcium. *Ind. Eng. Chem.* (*Anal. Ed.*), **12**, 118-20.

Tore Holth (1949). Separation of calcium from magnesium. A critical study. *Anal. Chem.*, **21**, 1221-6.

THE ESTIMATION OF IRON IN PLANT MATERIAL

By A. C. MASON

The lack of precision of methods for estimating iron in small samples of plant material is well recognized by workers engaged in this field. That there should be difficulty might appear surprising as several reliable and sensitive reagents are available for the colorimetric determination of microgram quantities of iron in solution.

With the intention of devising a precise method for estimating quantities of iron in the range 1-10 μg. in apple leaf samples, a critical investigation of available methods was undertaken in order to discover sources of error. A brief report on this work is presented here in the hope that some of the facts which have emerged may be of interest to other workers engaged on plant analysis.

Dry ashing procedure.

This method was selected for study first because the iron may be concentrated into a small volume, so ensuring the maximum sensitivity. The sample was heated at 450° C. for one hour and the resulting ash dissolved in dilute hydrochloric acid. The insoluble residue was separated, and iron adsorbed on the silica recovered by fusion with sodium carbonate. Estimation was by means of the pink colour developed with $\alpha\alpha'$-dipyridyl using the " Spekker " absorptiometer and 1 cm. micro-cells. By this method between 1 and 10 μg. of iron could be determined with what at first appeared to be reasonable precision, but further experience showed the method occasionally gave erratic results (Mason, 1950). Apparently the sodium carbonate fusion did not recover all the iron adsorbed on the silica ; spectrographic evidence supported this view.

Removal of silica by hydrofluoric acid treatment.

Removal of the interfering silica was attempted by the usual hydrofluoric acid treatment ; difficulties in handling small quantities of hydrofluoric acid were avoided by using a combination of purified ammonium fluoride and sulphuric acid. Replicate estimations of iron in a standard well-mixed sample of plant material were made. The silica remaining after solution of ash in dilute hydrochloric acid was separated and treated with the ammonium fluoride and sulphuric acid on platinum foil. The residue after fuming to dryness was dissolved in hydrochloric acid and added to the main bulk of solution. Estimation by the method described above gave the following results, 80, 71, 88, 87, 77, 75 p.p.m. These values were discordant and low compared with the finally accepted value for this sample of 94 p.p.m.

At the time it was thought that the low figures were due to the formation of non-ionizing complex fluorides. Later experience suggested that the iron may be bound as complex sulphates.

Acid digestion procedure.

In view of these unavoidable losses by adsorption of iron in the dry ashing procedure, experiments were made with the so-called wet ashing or digestion methods. Piper (1942) claims that adsorption losses are completely avoided in this way. Unfortunately, however, those procedures which conclude by heating with concentrated sulphuric acid suffer in sensitivity because considerable dilution is required to prevent precipitation of calcium sulphate and other salts after neutralization. When precipitation occurred after slight dilution, appreciable quantities of iron were carried down.

The digestion method recommended by Piper (*loc. cit.*) was tested and it was confirmed that no precipitation of silica occurred. His method consists in heating the sample with a mixture of nitric, perchloric and sulphuric acids, the excess of nitric and perchloric acids being removed by finally heating the sulphuric acid strongly. The results of replicated determinations on the standard sample (Table I) were again low and variable, probably owing to the formation of soluble complex iron compounds.

Avoidance of high blanks.

The Piper digestion method was found unsatisfactory for very small quantities of iron because of the high blank values for the reagents. It was essential to redistil the nitric and perchloric acids before use. Iron was removed from the sulphuric acid by treating with hydrochloric acid and extracting with amyl acetate.

TABLE I.

IRON CONTENT OF 100 MG. OF STANDARD SAMPLE OF APPLE LEAVES AS DETERMINED BY VARIOUS METHODS.

	Method.	Iron content in μg.
A.	HNO_3, $HClO_4$, H_2SO_4 mixture, after Piper.	6·4, 7·1, 6·8, 6·4
B.	H_2SO_4, H_2O_2 mixture. No heating of final solution.	7·6, 8·2, 8·6 and other values considerably lower but not determined.
C.	H_2SO_4, H_2O_2 mixture. Final solution heated as described in text.	*1st run.* 9·3, 9·4, 9·4, 9·6, 9·6, 9·6, 9·6 *2nd run.* 9·6, 9·6, 9·1, 9·6, 9·2, 9·6, 9·2 *Mean.* 9·45

TABLE II.

BLANK VALUES ON REAGENTS BEFORE AND AFTER PURIFICATION.

Combination of reagents tested.	Before purification.	After purification.
Perchloric acid digestion. 3 ml. HNO_3 + 0·2 ml. $HClO_4$ + 1 ml. H_2SO_4 + 10 ml. NaAc.	30 μg	2·5 μg
Hydrogen peroxide digestion. 1 ml. H_2SO_4 + 1 ml. 30% H_2O_2 + 10 ml. NaAc.	9 μg	1 μg

As plant material may be oxidized by sulphuric acid in conjunction with 30 per cent hydrogen peroxide, which is free from iron, it was possible, by using these two reagents, to achieve satisfactory low blank values (see Table II). This method was developed as described later, after study of the formation of iron complexes.

Effect of digesting standard solutions with sulphuric acid.

Replicated estimations of iron in the standard sample digested by the sulphuric-peroxide method yielded low and variable results (Table I, B), so the effect of the digestion procedure on standard iron solutions was investigated. The latter were prepared from pure iron wire and two series of colours developed with $\alpha\alpha'$-dipyridyl and hydroxylamine hydrochloride. Sulphuric acid was added to both, but one series was not digested and this gave what is referred to as the "ideal curve". The other series was digested and, surprisingly, the results were low and erratic. If, however, the digested series was heated in a boiling water bath for thirty minutes, as described later, the values agreed with the "ideal curve".

Thus, even in the absence of soluble phosphates and silicates, it seems that complex non-ionized iron compounds are formed by heating with concentrated sulphuric acid.

Breakdown of non-ionizing complexes.

If, indeed, iron is lost as non-ionizing complex compounds formed following dehydration during acid digestion, then treatment is necessary to break them down to the ionic state. Simple boiling of the diluted acid solution did not accomplish this, but heating in a boiling water bath after adding $\alpha\alpha'$-dipyridyl and a reducing agent did enhance the pink colour. It was also shown that the concentration and kind of reducing agent affected the colour intensity. Hydroquinone, which had previously proved satisfactory when used in the cold could not be used now because of the coloured decomposition products formed on heating. Other reducing agents were tried, e.g. lactose, arsenious oxide, hydrazine sulphate, metol, sodium hydrosulphite and hydroxylamine hydrochloride. The last was selected as the most satisfactory, provided it was purified before use.

Brief description of the method finally evolved.

100 mg. of sample is heated with 1·0 ml. of concentrated, iron-free, sulphuric acid until thoroughly charred ; after cooling, 0·25 ml. of 30 per cent Analar hydrogen peroxide is added and heating continued till further charring occurs ; more hydrogen peroxide is added and the process continued until the solution remains quite clear. After dilution to a volume of about 2 ml., the acid is neutralized by adding 10 ml. of 3·5 Molar sodium acetate. There is no danger of adding excess of this solution as it is self buffering within the pH range of 4 to 7 required for full development of the colour. 1·0 ml. of 0·25 per cent solution of $\alpha\alpha'$-dipyridyl in Normal hydrochloric acid is added, followed by 6·5 ml. of 30 per cent hydroxylamine hydrochloride. The mixture is heated in a boiling water bath for thirty minutes, by which time the colour is fully developed. After cooling, the volume is made up to 25 ml. and the solution " spekkered " in a 4 cm. cell with heat absorbing and Ilford No. 604 filters.

A blank on all reagents is run concurrently. The difference between the drum readings for sample and blank is referred to a standard calibration curve for determination of the iron content of the sample. The hydroxylamine hydrochloride and sodium acetate solutions are freed from iron by treating with " oxine " and extracting with chloroform according to the method of Gentry and Sherrington (1950).

Full details of the method, including purification of reagents, will be published elsewhere in due course.

Effect of the silicon content of the sample.

The success of the method depends on avoiding the formation of insoluble silica which adsorbs iron from solution. In the acid digestion, silicon remains in solution, presumably as complex metasilicates, but if large quantities of silicon are present, as, for example, in cereals, it is precipitated as silica during the acid digestion. In such cases, the method described is unsuitable.

Precision and sensitivity of the method.

The figures given in Table I, C show that a satisfactory degree of precision can be achieved when replicate analyses are made on a standard well-mixed sample of apple leaves.

It was originally hoped to use no more than 25 mg. of sample per determination, but because of the dilution necessitated by the acid digestion a sample of 100 mg. is used, giving a working range of from 4 to 40 μg. of iron.

Acknowledgement.

Thanks are due to Mr. E. C. Wills who carried out most of the practical work in this investigation.

Summary.

A report is given of an investigation into sources of error inherent in micro-chemical methods for estimating iron in small quantities of plant material. An outline is given of a method which, by reducing these errors, enables quantities of iron in the range 4 to 40 μg. to be estimated with a standard error of 2 per cent. The method depends on an acid digestion of the sample and development of a colour with $\alpha\alpha'$-dipyridyl and concentrated hydroxylamine hydrochloride, heating in a water bath to break down un-ionized complex iron compounds.

References

Gentry, C. H. R., and Sherrington, L. G. (1950). Extraction and photometric estimation of some metals with 8-hydroxyquinoline. *Analyst*, **75**, 17-21.

Mason, A. C. (1950). The estimation of phosphorus, potassium, calcium, magnesium, iron, manganese and nitrogen in plant material. *Rep. E. Malling Res. Sta. for 1949*, 111-15.

Piper, C. S. (1942). Soil and Plant Analysis. Monograph, Waite Agric. Res. Inst., Adelaide.

PLANT PATHOLOGY

RASPBERRY VIRUS DISEASES : A SURVEY OF RECENT WORK*

By C. H. CADMAN and R. V. HARRIS†

Introduction.

The considerable research on the virus diseases of wild and cultivated raspberries of the past thirty years has conclusively shown that the spread and accumulation of these diseases in vegetatively propagated planting stocks is a major factor in the successive decline and disappearance of leading commercial varieties which has hitherto characterized, and frequently jeopardized the fortunes of, the raspberry growing industry.

Major contributions to this field have, since the early 1920's, been made by Bennett, Rankin, Cooley and Zeller in the United States of America, by Chamberlain in Canada, and by Harris in England. That progress has been slow is due, in the main, to the technical difficulties inherent in any investigation of the virus diseases of woody or semi-woody crop plants.

None of the viruses infecting raspberries so far identified has proved to be transmissible by seed or by mechanical inoculation other than grafting, neither has any proved to be transmissible to hosts outside the genus *Rubus*. It has, therefore, not yet been possible to extract and study the viruses *in vitro*, and the identification of the economic diseases and of their component viruses has perforce been based exclusively on test transmissions to " indicator " red raspberry varieties and *Rubus* species, by grafting and by insect vectors.

Disease analysis by insect transmission.

Workers in North America early established that two aphid species of common occurrence on raspberries there, *Amphorophora rubi* Kalt. and *Aphis rubiphila* Patch, were vectors of the Red Raspberry Mosaic and Leaf Curl diseases respectively, and the identification of raspberry virus diseases has there been carried out mainly by insect transmissions. Bennett (1927, 1932), working principally with *A. rubi* and using the American black raspberry, *Rubus occidentalis*, as a test plant, was able to show that this aphid was a vector of diseases designated Yellow Mosaic and Red Raspberry Mosaic.‡ He recognized several grades of virulence in the latter but his experiments were not carried far enough to provide precise information on the etiology of these diseases or on the vector relations of the causal viruses.

It was not until 1947 that conclusive evidence that *Amphorophora rubi* Kalt. and *Doralis* (Aphis) *idaei* V.d.G. were vectors of certain raspberry viruses in Great Britain was obtained by Cadman and Hill working in Scotland. They effected transmission to red raspberry varieties only by using large numbers of viruliferous aphids per test plant, and subsequent attempts to repeat their results with small numbers (10-20) of aphids per test plant have largely failed. These findings parallel those of Bennett in America and are thought to be due to the high resistance of red raspberries (*R. idaeus*, *R. strigosus*) to insect borne infection. Recent experiments in Scotland have, however, confirmed the assertion frequently made in American literature that, conversely, the American black raspberry, *R. occidentalis*, is extremely susceptible to infection by means of aphids. The results of these, and other experiments with the native *R. saxatilis*, have indicated that, as in North America, *A. rubi* is the principal vector of raspberry viruses in Britain. *R. occidentalis* has, however, not proved to be a differential indicator as the symptoms produced on this host by different viruses have, so far, proved indistinguishable from one another and are closely similar to those on *R. occidentalis* described as Red Raspberry Mosaic by American authors. Analysis of economic diseases by means of the insect vectors has thus not progressed far either in North America or Britain.

* Based on a paper read to the Seventh International Botanical Congress, Stockholm, July, 1950.

† A.R.C. Scottish Raspberry Investigation, Dundee.

‡ Later named Green Mottle Mosaic by Cooley (1936).

Disease analysis by graft transmission.

Lacking an exact analytical technique, much reliance has had to be placed on the patently limited method of analysis by means of graft transmissions to " indicator " hosts.

This technique only provides for a classification of diseases and viruses according to the differing symptoms they produce on a selected range of indicator hosts, a most unreliable basis for deductions of true etiological significance.

The value of such data depends greatly on the range of sensitivity and differential reactivity of the " indicator " hosts employed, and on the subjective interpretation of symptoms. Analogous diseases have been thus described in North America and Britain, but no proofs have, as yet, been provided of the existence of identities or relationships between or within the groups of viruses endemic to either country.

In their work at East Malling, Harris (1940) and Prentice (1950) used only varieties of *R. idaeus* as indicators, principally Baumforth's Seedling B and Norfolk Giant. Cadman, at Dundee, extended the range of varieties used and included also the species, *Rubus henryi*, *R. saxatilis* and the American black raspberry, *R. occidentalis*. The results of the latter work in Scotland have recently confirmed the existence of two principal groups of virus diseases having features in common with, but a wider connotation than, the Mosaic 1 and Mosaic 2 groups distinguished by Harris (1940). Group 1 designates those distinct diseases which appear to be of single-virus origin, and which produce visible mosaic symptoms of some description on all European varieties of *R. idaeus* examined. Group 2 includes diseases that are expressed only by a few of such varieties and are carried without visible symptoms by others. Certain of these are, provisionally, termed " latent mosaic diseases " because they were discovered in stocks of *R. idaeus* varieties hitherto regarded as virus-free by the use of other *Rubus* sp. as indicators. This grouping is purely empirical and does not imply relationship or, in fact, any other character common to the diseases within each group.

Synopsis of diseases so far distinguished.*

Group I.

Vein-chlorosis mosaics are characterized by an indistinct chlorotic banding of the smaller leaf veins simulating vein clearing, and not subject to masking under warm weather conditions. This class includes three distinct diseases, provisionally termed mild, medium, and severe, vein chlorosis respectively. All are thought to be of single-virus origin and some evidence of strain relationship between the causal viruses exists. The first of these diseases is present in all " healthy " stocks of Baumforth's Seedling B examined ; the second is commonly present in commercial stocks of all European varieties and is the disease found to be transmissible by *R. idaei* V.d.G. by Cadman and Hill (1947). The third, severe vein clearing, first found on Norfolk Giant, has since been identified on commercial stocks of Lloyd George and other varieties as a severe chlorosis.

Vein-banding Mosaic, of which only one type has been found, is characterized by conspicuous chlorotic banding of the main veins, and down-curling, of the leaves, these symptoms being masked on foliage produced under warm weather conditions. The disease is thought to be the Mosaic 1 of Harris (1940).

Yellows diseases, of which a number have been distinguished, have only recently been shown to be caused by viruses. In general, leaf symptoms consist of partial or complete chlorosis, with bright yellow coloration, of the interveinal tissues, outlining the, initially dark green, veinal network. Symptoms tend to be most pronounced in early spring on the leaves of fruiting laterals and the lower leaves of young canes, subsequently appearing as an indistinct patchy chlorosis of foliage on the latter. Two types, mild and severe, have been distinguished by graft transmissions to Norfolk Giant and there is evidence that the two diseases are caused by related strains of one virus. It is also probable that other strains of this virus are responsible for the yellows diseases of Devon and certain other varieties.

Leaf Curl is characterized by severe leaf curling symptoms and necrosis on Norfolk Giant and Baumforth's B. (Harris *et al*, 1943). On other varieties this disease produces yellow blotching and other forms of leaf chlorosis. It is analogous, in certain features only, to the North American Leaf Curl and Yellow Blotch-Curl diseases (Bennett, 1927, 1930, Chamberlain, 1938). The vector is unknown.

Rubus Stunt, a lethal disease (Prentice, 1951) analogous to the North American Loganberry Dwarf (Zeller, 1927) causes sterility, dwarfing and proliferation of canes. Certain recent outbreaks in southern England have reached epidemic dimensions.

Three other diseases, referable to Group 1, have been identified in Scotland but their significance may be purely local.

* For illustrations see p. 203.

Group II.

Mosaic 2, defined by Harris (1940) is characterized by a leaf pattern of irregularly distributed, sharply defined and incised chlorotic spots not masked by warm weather conditions. Two types, mild and severe, have been identified on Norfolk Giant and Baumforth's B, and it seems likely that each is of single-virus origin though their inter-relations are unknown. Burnett Holm Seedling is the only other European variety examined that has proved to express visible symptoms on infection ; the majority behave as symptomless carriers.

Latent mosaic diseases. Leaf-mottle causes conspicuous chlorotic spotting, resembling Mosaic 2 conditions on Malling Landmark and certain other varieties, and necrosis on *Rubus henryi*. It is carried without symptoms by Norfolk Giant and Baumforth's B and is widely distributed in current commercial stocks of these varieties.

Other latent mosaic diseases, producing necrosis on *Rubus henryi* but distinct from Leaf-mottle, have been found in otherwise healthy stocks of Lloyd George (New Zealand stock), St. Walfried and Malling Landmark. Their inter-relationships are at present undetermined.

Curly Dwarf disease, described by Prentice and Harris (1950) may also belong to this group. Infected Baumforth's B plants show severe leaf-curling and proliferation of canes, and it is not yet clear whether this disease is carried without symptoms by Norfolk Giant, Lloyd George and other varieties.

Bushy Dwarf is certainly carried without visible symptoms by Norfolk Giant, but induces dwarfing of canes and down-curling of leaves, accompanied by diffuse chlorosis, on Lloyd George. Proof has not yet been provided that this disease is etiologically distinct from Curly Dwarf.

A tentative assessment of raspberry virus diseases.

The foregoing list, though probably not exhaustive, is thought to comprise the principal components of the complex diseases responsible for failure in vigour of cultivated raspberries in Scotland. Assessment of the relative importance of the individual diseases so far identified must remain largely speculative until the analysis is further advanced. At present, complex diseases can readily be synthesized by grafting together plants infected with apparently simple diseases, but a similarity between the resultant symptoms and those of one of the economic diseases cannot, alone, be accepted as proof of identity. Difficulties of interpretation are enhanced by the facts that no known stocks of any commercial variety are completely virus free, and few of the viruses identified have been separated from contaminant latent mosaic viruses. The opinions tentatively held at present are as follows.

Leaf Curl and Rubus Stunt, though both causing lethal or crippling diseases, are considered to be of minor and local significance. The remaining diseases of Group I individually produce effects on vigour and cropping roughly proportional to the visual degree of chlorosis and resultant metabolic disturbance. Joint infection with any two or three of these may, however, result in the development of much more severe diseases, depending on which particular virus strains are involved. These effects are enhanced by an infection and weakening of plants with Group II diseases.

The position with Group II diseases is more obscure and more closely bound up with varietal differences in reaction. For example, degenerate stocks of Lloyd George have consistently proved to contain a combination of Mosaic 2, Bushy Dwarf and Yellows diseases ; this appears to have no effect on Malling Promise or Newburgh. Again, commercial stocks of Malling Enterprise and Malling Jewel, though vigorous, contain a mixture of severe Mosaic 2, Leaf-mottle, and probably Mild Yellows viruses. But this combination produces severe effects on Norfolk Giant (sensitive to Mosaic 2) and Malling Landmark (sensitive to Leaf-mottle).

From this survey it is evident that progress in raspberry virus research is closely dependent on the evolution of more adequate analytic techniques and that much remains to be done before a comprehensive picture can be presented. Apart from the salient problems referred to, little is yet known of the precise effects of individual viruses on vigour and cropping, of their rates and mode of spread in different varieties, or of the inter-relations of the viruses endemic to the various raspberry growing areas of the world. Such information is of vital importance to the growing of the crop, the management of certification schemes and the interchange of stocks between different areas and countries.

Acknowledgements.

The more recent research detailed above was made under a grant from the Agricultural Research Council, to whom acknowledgements are made.

Summary.

1. Progress in the identification and evaluation of raspberry viruses has been necessarily confined to analysis by insect and graft transmissions to indicator hosts.

2. Usefulness of insect transmission for this purpose is limited by the high resistance of red raspberry varieties (*Rubus idaeus*) to infection by this means, and because the highly susceptible *R. occidentalis* has proved not to be a differential indicator.

3. The scope of graft analysis has recently been increased by the use as indicators of (*a*) an extended range of red raspberry varieties, and (*b*) the species *Rubus saxatilis* and *R. henryi*.

4. Some nine types of virus disease are briefly described and for convenience are provisionally grouped into those which are, and those which are not, expressed by all the indicator *R. idaeus* varieties in present use.

References

Bennett, C. W. (1927). Virus diseases of raspberries. *Tech. Bull. Mich. Agr. Exp. Sta.*, **80**.

——— (1930). Further observations and experiments on the curl disease of raspberries. *Phytopathology*, **20**, 787-802.

——— (1932). Further observations and experiments with mosaic disease of raspberries, blackberries, and dewberries. *Tech. Bull. Mich. Agr. Exp. Sta.*, **125**.

Cadman, C. H. and Hill, A. R. (1947). Aphid vectors of European raspberry viruses. *Nature*, Lond., **160**, 837.

Chamberlain, G. C. (1938). Yellow blotch-curl : a new virus disease of the red raspberry in Ontario. *Canad. J. Res. C.*, **16**, 118-24.

Cooley, L. M. (1936). The identity of raspberry mosaics. *Phytopathology*, **26**, 44-56.

Harris, R. V. (1940). Mosaic diseases of the raspberry in Great Britain. II. Experiments on transmission and symptom analysis. *J. Pomol.*, **17**, 318-43.

———, Bryce, A. D. and Foister, C. E. (1943). A leaf curl disease of raspberry in Scotland. *Rep. E. Malling Res. Sta. for 1942*, 48-50.

Prentice, I. W. (1951). Rubus Stunt. *J. hort. Sci.*, **26**, 35-42.

Prentice, I. W. and Harris, R. V. (1950). Mosaic disease of the raspberry in Great Britain. III. Further experiments in symptom analysis. *J. hort. Sci.*, **25**, 122-127.

Zeller, S. M. (1927). Dwarf of blackberries. *Phytopathology*, **17**, 629-48.

Fig. 1.

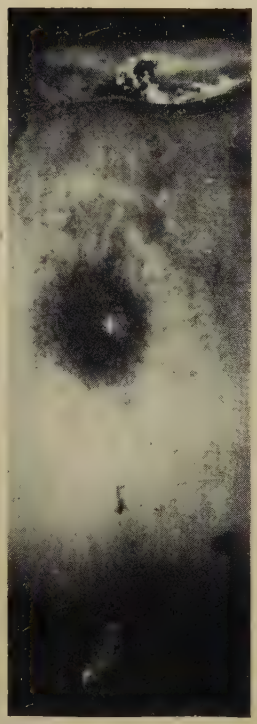


Fig. 2.

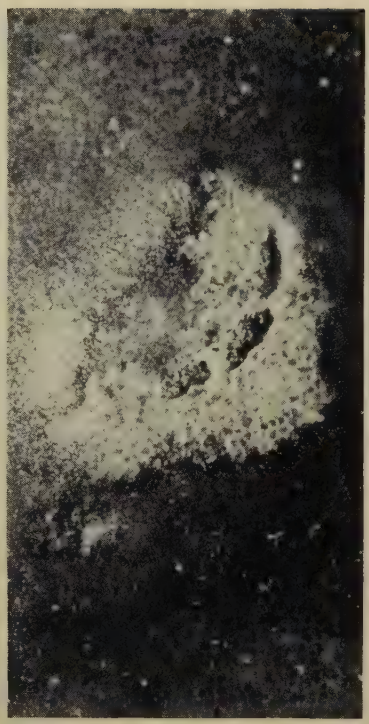


Fig. 3.

Fig. 1.

Hail damage in Bramley's Seedling. Note accentuation of pitting as a result of later growth of the healthy tissue surrounding the large pit near the "eye".

Fig. 2.

Early stages of rotting around small but obvious split in skin overlying hail bruise.

Fig. 3.

Enlarged view (× 33 approx.) of crescent-shaped splits in skin overlying hail bruise. This probably represents the early stage of the open wound seen in Fig. 2.

Fig. 4.

Fig. 5.

Fig. 4.

Brown Rot lesion progressing concentrically around lenticel in Bramley's Seedling.

Fig. 5.

Enlarged view (× 33 approx.) of lenticel illustrated in Fig. 4. No apparent abnormality ; the darker patches are deep shadow from the illuminant.

BROWN ROT OF APPLES : NOTE ON INFECTION ASSOCIATED WITH HAIL BRUISES AND LENTICELS

By M. H. MOORE

Infection through small splits following hail damage.

In mid-September, 1950, the fruit in a plantation of large Bramley's Seedling trees near Maidstone, Kent, was found to be liberally infected with Brown Rot (*Monilia fructigena*). The grower thought that some of the infections were occurring in undamaged fruits. The wound origin of many of the infections was obvious ; the cracks due to Scab (*Venturia inaequalis*) and the tunnellings of Codling Moth (*Cydia pomonella*) larvae were prominent. In addition, there were unmistakable signs on the north-west side of every tree of damage from a hailstorm that had occurred some six weeks before, which had pitted the exposed surfaces of many fruits (Fig. 1). The hailstones apparently had not broken the skin in most cases, yet Brown Rot infections not more than three or four days old were present, and many of them appeared to be centred on individual hail bruises. A hand-lens examination showed a very small break in the skin at the centre of some of the lesions, and in others, a small crack of uncertain origin was visible to the naked eye (Fig. 2). Microscopic examination confirmed that there were small, and apparently recent, crescent-shaped splits in the centre of the Brown Rot lesions in nearly all cases where there was no obvious break in the skin. An examination of those hail bruises where no infection had occurred suggested that the splits did not arise directly from the impact, but were the result of later stresses set up in the skin overlying the necrotic tissue of the bruise by the growth of the normal tissues surrounding it (Fig. 3). The obvious splitting (Fig. 2) was probably a development from this early stage.

Hail damage is a well-known agent in Brown Rot infection of fruits (Wormald, 1935 ; Moore, 1950), but the usual reference is to the breaking of the skin by the impact of the hailstone. In violent storms this is not uncommon ; indeed, instances have been encountered where pieces of tissue had been gashed out by hailstones, and in these cases Brown Rot almost invariably followed. Infection through later splits in unbroken skin, however, has hitherto not attracted notice.

Infection through a lenticel.

One lesion was found that on close examination showed no evidence of surface injury within the affected area, which was developing concentrically around a lenticel (Figs. 4, 5). Horne (1933) described a laboratory method of inoculating apples through the lenticels, and, when experimenting with several different species of fungi, found that all, including the Brown Rot fungus, were able to pass through the lenticels and cause decay of segments of apple fruits. Wormald (1935) considered that penetration through a lenticel under normal plantation conditions is unlikely. Numerous observations up to the present support this view, but the present research provides evidence that it can occur. It may be that conditions, and especially frequent heavy rain, were specially favourable for occasional lenticel invasion in the 1950 autumn.

Acknowledgements.

The writer is indebted to Miss J. M. Buttfield of the National Agricultural Advisory Service, for assistance in the field, and to Miss E. C. Thompson for photographs (Figs. 3, 5).

Summary.

Brown Rot infection has been noted in Bramley's Seedling apples in the plantation through two apparently unusual channels : (1) small skin-fissures overlying hail bruises, which had occurred some six weeks earlier, and (2) a lenticel.

REFERENCES

HORNE, A. S. (1933). Biological work on fruit. *D.S.I.R. Rep. Food Invest. Bd. for 1932*, 279-300.
MOORE, M. H. (1950). Brown Rot of apples : fungicide trials, and studies of the relative importance of different wound-agents. *J. hort. Sci.*, **25**, 225-34.
WORMALD, H. (1935). The Brown Rot diseases of fruit trees. *Bull. Minist. Agric., Lond.*, **88**, 50 pp.

THE INFLUENCE OF ROOTSTOCK ON SPRAY DAMAGE IN APPLE

By A. P. PRESTON, M. H. MOORE and MARGERY BENNETT

Introduction.

Early indications that the rootstock on which an apple variety is worked can influence its susceptibility to spray damage were shown at East Malling by Frampton (1928) and Moore (1934), working with Cox's Orange Pippin and Stirling Castle sprayed post-blossom with lime-sulphur or Bordeaux mixture.

Moore (1946) observed extensive leaf-drop and scorch on Cox's Orange Pippin following a 1 per cent lime-sulphur spray, without a spreader, applied at Petal Fall and Fruitlet stages ; where a spreader was included there was no damage. Worcester Pearmain showed little damage with either spray. Cox's Orange Pippin on M.II and M.X showed an intermediate reaction, but those on the vigorous M.XIII and M.XVI were more affected than those on the less vigorous M.I, M.III, M.V, and M.IX. Fruit-drop also was affected by the rootstock, trees on M.IX in this case also being better able than the others to tolerate the more damaging spray.

Tydeman (1933, 1943) produced a series of rootstocks, having M.IX as one parent, that covered a wide range of vigour and precocity. It was decided to use some eight year old trees of Cox's Orange Pippin on eighteen of these stocks to test whether they showed a range of resistance to spray damage.

The parentage of these new rootstocks is shown in Table III, together with the vigour (as mean cross-sectional area of trunk) of the worked trees at nine years old.

EXPERIMENT I, 1949.

Material.

The trees, together with similar ones on some of the standard Malling rootstocks as controls, had been planted at three years old in double rows and grouped according to their expected vigour, i.e. dwarf, intermediate, and vigorous, as based on early field performance. With a standard distance of 6 feet between the rows, the dwarfs were planted 3 feet, the intermediates 4½ feet, and the vigorous 6 feet apart in the rows. Individuals in each group were arranged as two-tree plots within each of five randomized blocks. The restrictions in the experimental layout allow of only general comparison between the vigour groups, and, to aid in detecting any variation due to the position of the groups, certain rootstocks were included in more than one group, viz. M.VII in both dwarfing and intermediate groups, and 3428 in both intermediate and vigorous groups.

Method.

On 10th June, when the trees were at Fruitlet stage, a 1½ per cent lime-sulphur spray, estimated to cause moderate damage, was applied to all trees from a 2 h.p. mobile machine working at about 300 lb. pressure per square inch. A preliminary survey had confirmed that there was no existing leaf-scorch apart from the usual " Cox Spot ", and the ground around the trees had recently been cleared of leaves and weeds. Some leaves were showing scorched patches on 14th June, and by 17th the scorching was very clearly seen ; leaf-drop started the following week. A category record for leaf-scorch and leaf-drop was made for every tree on 23rd June. Size of tree was allowed for in assessing the damage into categories, and, owing to the close planting of these dwarf pyramids, only the fallen leaves within an area immediately below each tree were recorded. The categories were as follows :

Leaf-scorch :

0 no leaves scorched.
1 a few leaves scorched on one or two shoots.
2 scorched leaves lightly scattered over tree.
3 30-50 per cent leaves scorched.
4 over 50 per cent leaves scorched.

Leaf-drop :

0 no leaves dropped.
1 a few leaves dropped.
2 many leaves dropped, ground partly covered.
3 ground covered with leaves.
4 ground covered with layers of leaves.

Results.

Field notes show that leaf-drop was still occurring on 1st July, after the record was made, but as a period of hot, dry weather had set in, no further record was made as the results would probably have been complicated by drought effects, especially in view of the close planting. The trees carried a light crop and fruit-drop did not occur. Analyses were made separately on the leaf-drop and scorch records for each class of rootstock, and in every case there were significant differences. The results are shown (Table I) as the average category of ten trees on each stock.

TABLE I.

LEAF RECORDS FOLLOWING 1½ PER CENT LIME-SULPHUR SPRAY ON COX'S ORANGE PIPPIN, JUNE, 1949. MEAN CATEGORY OF TEN TREES ON EACH STOCK.*

VIGOUR GROUP.†	LEAF-DROP.							
Dwarf								
Stock	3424	3419	3431	3413	341	3426	M.IX	M.VII
Category ..	1·0	1·0	1·0	1·1	1·2	1·3	1·3	1·6
Intermediate								
Stock	3420	3423	3421	M.VII	3436	3422	3428	M.II
Category ..	1·0	1·1	1·1	1·3	1·4	1·5	1·9	2·1
Vigorous								
Stock	3437	3435	3414	3432	3428	3438	3430	M.XII
Category ..	1·1	1·6	1·7	1·8	2·3	2·9	3·4	3·9
	LEAF-SCORCH.							
Dwarf								
Stock	3426	3431	3413	M.IX	3424	341	M.VII	3419
Category ..	1·4	1·4	1·7	1·7	1·8	2·2	2·5	3·0
Intermediate								
Stock	3423	3421	3420	3436	3422	M.VII	3428	M.II
Category ..	1·2	1·2	1·2	2·0	2·5	2·7	2·9	3·0
Vigorous								
Stock	3437	3435	3432	3428	3414	3430	M.XII	3438
Category ..	1·9	2·0	2·1	2·2	2·4	2·5	2·6	2·9

* Figures bracketed together do not differ significantly.

† Vigour based on early woodgrowth and fruit-bud records (Tydeman, 1943).

EXPERIMENT II, 1950.

Method.

The 1949 trial was repeated on the same trees in 1950. On 9th June, at Fruitlet stage, a 1½ per cent lime-sulphur spray was applied to all trees. Any leaf-scorch already existing had been recorded for each tree, and the ground cleared, on 8th June. By 12th June slight leaf-drop was beginning on trees on M.XII, 3430, and 3435. On 20th, a category record for leaf-drop was made as hitherto ; likewise for leaf-scorch on 27th June.

Drought conditions were absent, but fruit-drop was obvious ; June drop had not yet begun. A record of the numbers of dropped fruitlets and of those remaining was made for every tree on 28th June, and the dropped fruitlets were classified for Sawfly and Scab.

Results.

There was no correlation between the values for leaf-scorch before and after spraying, and the analysis for leaf-scorch after spraying was therefore made without using a covariance factor. Trees on 3422 and on M.II in the intermediate vigour group showed most leaf-scorch, the difference just reaching significance ; much of the leaf-scorch was doubtless merged in the leaf-drop record by the dropping of the scorched leaves.

The analysis of the leaf-drop record was similarly made without using a covariance factor, and significant differences were found among the vigorous rootstocks (Table II).

Within each rootstock group there were significant differences also for dropped fruitlets, other than those with Scab and Sawfly, when expressed as a percentage of total fruits (on the tree and dropped) on 28th June (Table II).

TABLE II.

LEAF AND FRUIT RECORDS FOLLOWING 1½ PER CENT LIME-SULPHUR SPRAY ON COX'S ORANGE PIPPIN, JUNE, 1950.

VIGOUR GROUP.†	LEAF-SCORCH (MEAN CATEGORY OF TEN TREES ON EACH STOCK).*							
Intermediate								
Stock	3421	3420	3436	3423	M.VII	3428	M.II	3422
Category	1·0	1·1	1·1	1·2	1·2	1·3	1·7	1·8
	LEAF-DROP (MEAN CATEGORY OF TEN TREES ON EACH STOCK).*							
Vigorous								
Stock	3435	3437	3428	3432	3414	3438	3430	M.XII
Category	1·0	1·1	1·3	1·4	1·6	1·8	2·6	2·6
	FRUIT-DROP (PER CENT. DROP PER TREE).*							
Dwarf								
Stock	3431	3424	3426	3413	3419	341	M.IX	M.VII
Category	6·1	8·2	9·6	10·2	12·2	15·3	16·5	33·3
Intermediate								
Stock	3421	3420	3423	3422	M.VII	3436	3428	M.II
Category	4·5	4·7	6·1	9·2	20·4	21·0	27·1	33·1
Vigorous								
Stock	3435	3437	3432	3428	3414	3430	3438	M.XII
Category	19·6	24·0	34·6	40·3	49·9	72·0	75·0	84·0

* Figures bracketed together do not differ significantly.

† Vigour based on early woodgrowth and fruit-bud records (Tydeman, 1943).

Discussion.

In general, the more dwarfing rootstocks were associated with reduced spray damage, shown as leaf-scorch and leaf- and fruit-drop, and the vigorous stocks with increased damage. This is the more pronounced if rootstocks 3432, 3435, and 3437, originally classified as inducing vigour (Tables I and II), are regarded as intermediate or dwarfing, into which vigour groups they now fall (Table III).

Trees on the standard Malling rootstocks M.XII, M.II, and M.IX, included as controls in these experiments, behaved much as they had done in earlier trials in that damage tended to be greater on the more vigorous trees. The trees on M.VII and 3428, each in two different groups (Tables I and II), however, behaved inconsistently in 1950 as regards fruit-drop, which suggests that position or some other variant was a material factor in the fruit-drop data. This variation was not conspicuous in the

Table III.

Parentage of new clonal rootstocks: vigour and spray damage in Cox scions at 9 years old.

Rootstock reference number.	Parentage (Malling rootstocks). ♀ ♂	Tree-size based on field observations, 1950.	Cross-sectional area of trunk (cm.), 1949.†	Leaf-scorch,* 1949 and 1950.	Leaf-drop,* 1949 and 1950.
3426	VII × IX	very dwarf	2·0	2·4	1·6
3419	IX × IV	„ „	4·0	4·1	1·7
3431	XIII × IX	„ „	4·4	2·4	1·7
3413	II × IX	„ „	4·6	2·6	2·1
3420	V × IX	dwarf	6·2	2·3	1·9
3424	IX × V	„	6·4	2·9	1·4
3423	IX × V	„	7·0	2·4	1·8
3437	V × IX	„	7·4	3·3	2·4
3421	V × IX	„	7·6	2·2	1·6
M.IX		„	8·0	2·7	2·1
M.VII		intermediate	9·7	3·8	2·5
341	I × IX	„	10·1	3·2	2·0
3422	V × IX	„	11·1	4·3	2·0
3432	IX × XIII	„	11·1	3·1	3·2
3435	IX × XV	„	11·1	3·3	2·6
M.VII		„	11·7	3·9	2·2
3436	XVI × IX	vigorous	13·7	3·1	2·4
3428	IX × VII	„	13·7	3·5	3·6
3428	IX × VII	„	15·3	4·2	3·4
M.II		„	16·2	4·7	3·2
3414	II × IX	„	16·2	3·5	3·3
3438	IX × XII	„	18·0	4·5	4·7
M.XII		very vigorous	28·8	4·0	6·7
3430	XII × IX	„	39·5	4·0	6·0

* These figures were obtained by adding the mean category values for leaf-scorch and leaf-drop respectively for 1949 and 1950.

† Arranged in ascending order.

data for leaf-scorch and leaf-drop, and it may be that fruit-drop is a less reliable guide because of tree-to-tree variation in cropping among trees of which the more vigorous may still be in a vegetative stage of development, and would perhaps drop their fruits even without spray treatment (Moore, 1946, p. 85). Even when closely planted as dwarf pyramids, they have produced much annual wood growth after uniform, winter spur-pruning; trees on the very vigorous 3430 nevertheless cropped earlier than those on M.XII.

The vigorous rootstocks, 3430 and 3438, each of M.IX × M.XII parentage, behaved similarly to the vigorous M.XII control as regards spray damage, so the M.IX parent evidently had exerted less influence than the M.XII. Trees on M.IX and M.XIII, represented by two different progeny, 3431 (dwarfing) and 3432 (intermediate), also showed the alliance of vigour with susceptibility to spray damage, for 3431 induced less, and 3432 considerably more, than M.IX.

There were some exceptions to the general trend, but most of these fall within the range of the rather wide variation among trees in the same vigour group, especially as regards fruit-drop, and are thus non-significant. Trees on 3422, however, showed significantly less fruit-drop than those on M.VII, which are of similar vigour (Table III).

Thus from these and earlier experiments there is evidence that the rootstock influences spray damage in the scion. There is, therefore, some prospect of widening the narrow safety margin (Moore, 1940) between damage to the host plant and toxicity to the parasitic plant (the pathogen) to be controlled, in this case Apple Scab. Although the evidence is limited, it seems likely that the dwarfing induced by M.IX, and a measure of resistance to lime-sulphur damage, may be allied, and this of itself indicates that it is possible to breed and select rootstocks that can mitigate lime-sulphur damage in Cox's Orange Pippin. So far, however, there appears to be little prospect of a series of rootstocks that will induce resistance and yet cover a wide range of vigour, though a few of the crosses, e.g. 3422 for fruit-drop, and possibly 3436 for leaf-damage, may indicate a small beginning in this direction. On

the other hand, others, e.g. 3419 for leaf-scorch, and 3437 for both leaf-scorch and leaf-drop, provide an early suggestion of an alliance of low vigour with susceptibility to spray damage, a combination that might be useful in intensive experiments on spray damage, where small, closely-planted trees are desirable.

Further work is projected to ascertain whether the present series of new rootstocks, like the standard Malling ones (Moore, 1934), are able to influence susceptibility to Apple Scab in the scion. If even limited ability to induce resistance to spray damage and Apple Scab infection can be shown to occur together in any one or more pomologically desirable rootstocks, some advance might be possible towards reducing the number and increasing the safety of lime-sulphur sprays used for the control of Apple Scab on susceptible scion varieties.

Acknowledgements.

The writers are indebted to Mr. R. P. Longley of the Dominion Experimental Farm, Kentville, Nova Scotia, who helped to record the field data during the 1950 experiment. The Statistical Section kindly did the analyses.

Summary.

1. Dwarf-pyramid, winter-pruned trees of Cox's Orange Pippin, eight years old, on a series of new rootstocks and of standard Malling rootstocks were sprayed with 1½ per cent lime-sulphur at Fruitlet stage for two consecutive seasons, and leaf-scorch was recorded before and after spraying ; also leaf- and fruit-drop after spraying.

2. Significant differences among rootstocks within vigour groups were shown for leaf-scorch and leaf- and fruit-drop. In general, trees on dwarfing stocks were less damaged than those on vigorous ones, but there were exceptions.

3. The results are discussed in relation to a possible reduction of lime-sulphur damage through the genetical constitution of the rootstock.

References

Frampton, A. M. (1928). Preliminary report on the incidence and control of Apple Scab and Apple Mildew. *Rep. E. Malling Res. Sta. for 1926-7, II Suppl.*, 96-107.

Moore, M. H. (1934). Spraying and dusting experiments on the control of Apple Scab (*Venturia inaequalis*) and Apple Mildew (*Podosphaera leucotricha*) at East Malling in 1931-32. *J. Pomol.*, **12**, 57-79.

——— (1936). Some observations on the influence of manurial dressings and of certain other factors in the incidence of Scab (*Venturia inaequalis* (Cooke) Wint.) and of spray-injury in apples. *J. Pomol.*, **14**, 77-96.

——— (1940). A brief review of research work at East Malling on the control of Apple Scab. *Rep. E. Malling Res. Sta. for 1939*, 75-6.

——— (1946). Improving the field performance of standard protective fungicides. I. The place of spreaders in the spray programme for apple trees. *J. Pomol.*, **22**, 76-91.

Tydeman, H. M. (1933). Breeding experiments with " Paradise " apples. *J. Pomol.*, **11**, 214-36.

——— (1943). Further studies on new varieties of apple rootstocks. *J. Pomol.*, **20**, 116-26.

BLACK ROT AND LEAF SPOT OF APPLE DUE TO *PHYSALOSPORA OBTUSA* (SCHW.) COOKE

By J. E. CROSSE and MARGERY BENNETT

In mid-August, 1950, a report was received from an orchard in Kent of an extensive rotting of apple fruits shortly before picking. On each specimen examined there was a circular brown lesion with the pycnidia of a *Sphaeropsis* sp. developing immediately, under the skin. When the orchard was examined later a severe leaf-spot was found coextensive and roughly correlated with the fruit rot in intensity. From these spots the same fungus was consistently isolated.

The pycnidia on the fruits corresponded to the *Sphaeropsis* form of the fungus *Physalospora obtusa* (Schw.) Cooke, to which the Black Rot and Leaf Spot disease of apples in this country is usually attributed.

In the U.S.A. this fungus has long been known for its ravages of the apple orchards of the eastern states (Hesler, 1916). Occurring usually in the imperfect *Sphaeropsis* stage, it attacks fruits, leaves and branches, and in one or more of these forms the disease was at one time regarded as second only to Apple Scab in importance. In England only the leaf-spot phase has hitherto been described on orchard trees (Salmon, 1908), and the disease has therefore attracted little attention. It occurs uncommonly as a storage rot of apples (Kidd and Beaumont, 1924), but as a pre-harvest fruit rot it appears to be virtually unknown in this country. Apart from economic considerations, therefore, the occurrence of this form of the disease on the scale of this outbreak is of considerable interest. The following description is offered to facilitate the diagnosis and notification of any similar outbreak that may occur.

The orchard in which the disease was first noticed consisted of mature trees of the varieties Worcester Pearmain and Lord Derby. The leaf-spotting, which was equally severe on both varieties, had been observed earlier in the season and at that time attributed to spray damage. In one part of this orchard the majority of the leaves of some trees were infected. In contrast to the leaf-spot, there was a very marked difference in the intensity of the fruit rot on the two varieties. Thus, while it was estimated that by the middle of August 25-30 per cent of the Worcester crop was affected, diseased fruits of Lord Derby were only occasionally found. On later inspection the disease was discovered in another orchard nearby, but from among Worcester Pearmain, Beauty of Bath, Lord Derby, Bramley's Seedling, Newton Wonder, and Cox's Orange Pippin, the first named was the only variety affected.

Individual fruit lesions started as small spots, which enlarged to form dark-brown, flat lesions with an indefinite concentric zoning (Fig. 1). Infected fruits were subsequently reduced to small black mummies, and it is this stage of the disease that has suggested the name Black Rot. Pycnidia of the fungus appeared at an early stage, and the occurrence of these small, black fructifications under the skin was characteristic, distinguishing this disease from Brown Rot and Bitter Rot (*Gloeosporium* spp.). On Lord Derby the lesions were lobed, and the edge marked by a bright purple pigmentation. All the infections on Lord Derby fruits and a few on Worcester Pearmain had originated either through the eye or some obvious crack or insect puncture ; most of the Worcester Pearmain infections, however, could not be associated with any discernible wound. Spores obtained from the pycnidia by crushing them in water were oblong-ellipsoid, continuous, and varied from hyaline to light brown within a single pycnidium, appearing olive green in intermediate stages. The majority of spores measured 27μ—30μ × 12μ—14μ.

The symptoms on the leaves also were characteristic. Each lesion consisted of a small, circular, grey, membranous, primary spot from the edges of which secondary extensions of the infection took place. In the earlier stages these latter appeared as narrow purple crescents around the periphery of the primary spot ; these became confluent, and extended to form large, necrotic patches within which the identity of the original primary spot could still be recognized (Fig. 2). The early stage of extension recalled the name " Frog Eye " by which this leaf-spot is sometimes known in the U.S.A. Occasional *Sphaeropsis* fructifications were found on the foliage shortly before leaf-fall, but none was observed earlier.

It was clear from the absence of pycnidia on them in August that the leaves did not provide the inoculum for the fruit rot, and this suggested the existence of an alternative source common to both leaf and fruit infections. Dead twigs, and branches showing die-back, had already been observed in many trees, and when these were examined the pycnidia of a *Sphaeropsis* sp. were found in relative

abundance. Spores present in these pycnidia were similar in size and shape to those from the fruits, but were uniformly tan in colour and occasionally one-septate. The probability that this difference in colour represented merely a difference in spore maturity was investigated by the establishment of single-spore cultures from both sources. These fruit and wood isolates proved identical, and on inoculation to apple fruits both produced rot symptoms indistinguishable from those occurring naturally.

On the basis of pathogenicity and cultural characterististics, therefore, the *Sphaeropsis* sp. found on the wood proved to be the same as that previously observed on the fruits. Several mycelial isolations also were made from the edge of lesions on twigs with no pycnidia present, and all of these produced a rot when inoculated to fruits. The fungus was more widely distributed on the dead wood, therefore, than the presence of the fructifications indicated.

There appears to be no evidence that the fungus has a parasitic stage on branches and twigs in England, although it has previously been found here on dead apple wood. In the U.S.A., by contrast, it is known to be the cause of the " New York apple-tree canker " disease, a limb canker and die-back, so called because at one time it was extensively distributed in New York and other eastern seaboard states. In that country, however, it lives also saprophytically on twigs and branches killed by Fire Blight, winter injury, and other agencies. The occurrence of *Sphaeropsis* on the wood in the present outbreak, therefore, raises the question of its mode of activity on that medium. Further investigation of this problem is necessary since the evidence so far available is conflicting. Thus, while the purity of isolates from the edge of twig lesions sometimes suggested parasitism, wherever pycnidia of the fungus were found they were invariably associated with the fructifications of other fungi, especially that corresponding to *Myxosporium corticola* Edgert., the reputed cause of surface bark cankers. In one case particularly, where the *Sphaeropsis* pycnidia were observed on an apple canker together with *Nectria galligena*, its saprophytic status was manifest. The exact mode of activity on the wood is uncertain, therefore, but this does not detract from the undoubted importance of this stage as an overwintering source of inoculum for fruit and leaf infections the following year.

In the United States, spraying and the removal of overwintering stages on the wood and mummified apples have been the chief control methods recommended. Both Bordeaux mixture and lime-sulphur have proved effective in controlling the leaf-spot phase, and the decline of the disease in recent years has been attributed in part to the more general use of scab sprays. It must be emphasized, however, that both of the orchards concerned in the present outbreak have received the normal scab programme. The one most severely diseased received the full programme in 1950, and all post-blossom sprays the year before ; its history prior to this is unknown. The other orchard, however, had been fully and rigorously sprayed for many years, as the almost complete absence of scab testified. In these circumstances it is difficult to understand the factors underlying the sudden occurrence of the fruit rot, although the condition of one orchard at least suggested that the leaf-spot phase had been endemic for several years, and that attention was only directed to this following the appearance of the economically important phase on the fruit. The apparent failure of sprays to control the disease completely emphasizes the importance of removing dead wood, mummified apples, prunings, and any other other substrate on which the fungus might overwinter.

Summary.

An Outbreak of Leaf Spot and Black Rot of apple caused by *Physalospora obtusa* (Schw.) Cooke in its *Sphaeropsis* stage is fully described. In a search for an overwintering stage on dead wood, pycnidia were found of a *Sphaeropsis* sp. pathogenically and culturally identical with that on the fruits. Its role as a possible wood parasite is considered, and control measures are briefly discussed.

References

Hesler, L. R. (1916). Black-rot, leaf spot and canker of pomaceous hosts. *Bull. Cornell agric. Exp. Sta.*, **379**, 51-148.

Kidd, M. N. and Beaumont, A. (1924). Apple Rot fungi in storage. *Trans. Brit. mycol. Soc.*, **X**, 106.

Salmon, E. S. (1908). " Leaf-spot " diseases of the apple. *J. S.E. agric. Coll. Wye*, **17**, 316-19.

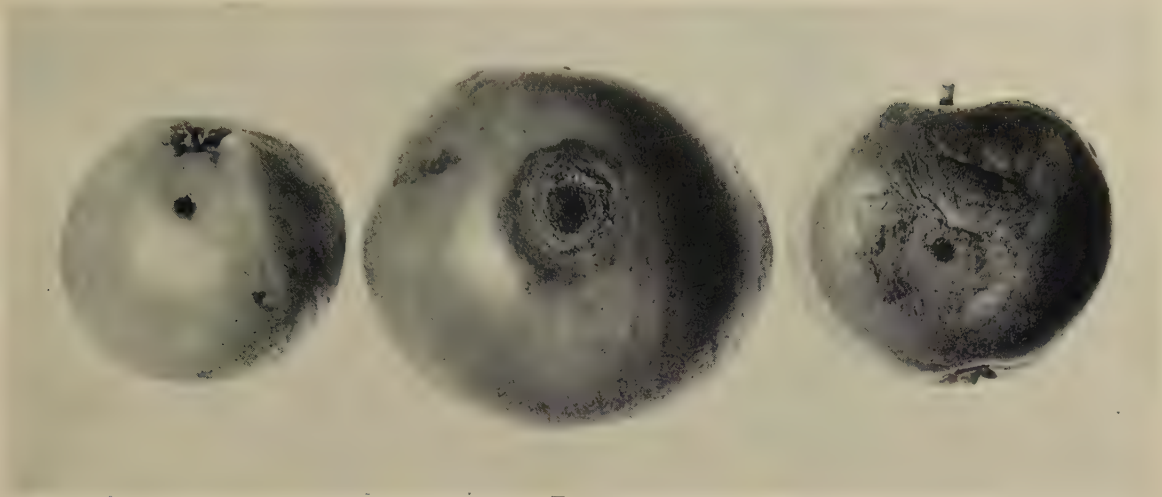


Fig. 1.

Black Rot of apples, on variety Worcester Pearmain, showing stages in the development of lesions. The concentric circles of *Sphaeropsis* fructifications can be seen on the surface.

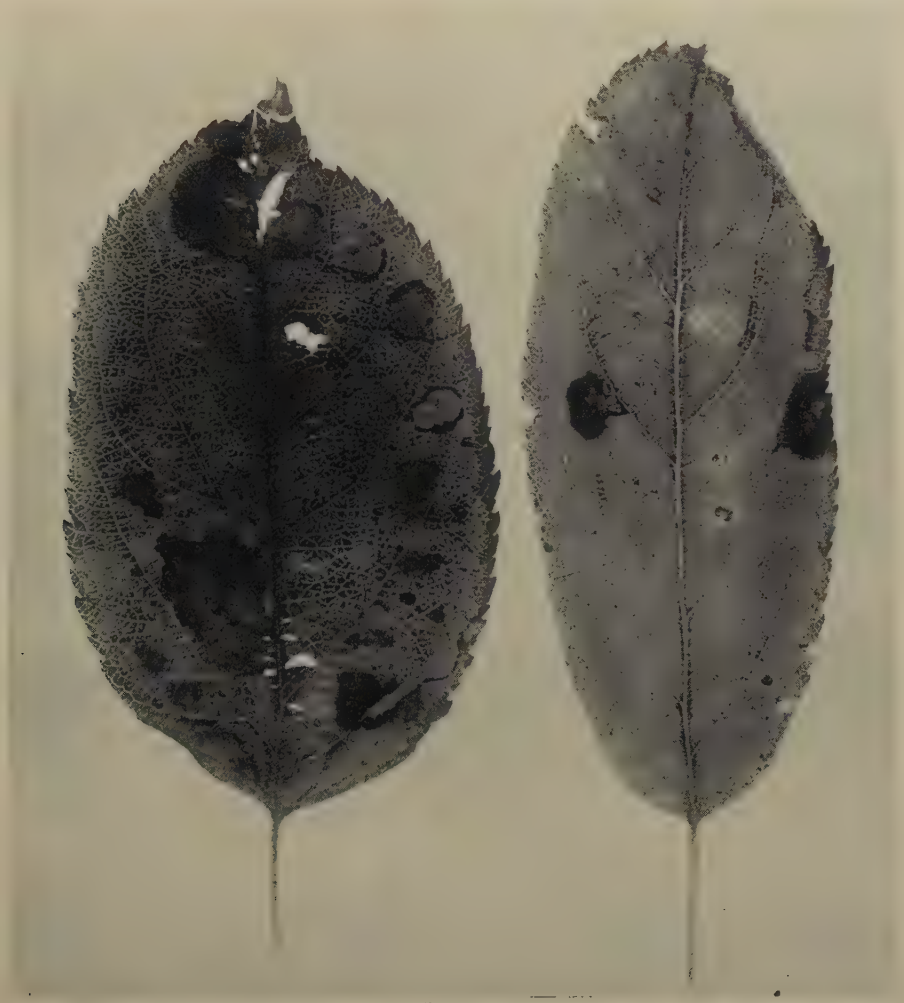


Fig. 2.

Leaf Spot of apple, on leaves of the varieties Lord Derby (left) and Worcester Pearmain (right).

[*face p. 138*

THE TREATMENT OF HOP SEED TO IMPROVE GERMINATION

By J. PAINE

Introduction.

The germination of hop seeds at East Malling has often proved unsatisfactory, and at times total failures have been recorded. During the three years 1948-50 untreated Fuggle and Golding seed gave an average of only 10 per cent germination. Similar difficulty was reported by Raum, and Bressman referred to the use of chilling and scarification to stimulate germination (*vide* Smith, 1949). Smith, in his own experiments in Oregon on the influence of moisture and low temperature, found that seed treatment improved germination. The following note describes experience with a method found of value at East Malling.

Seed material.

The Fuggle seeds used in 1948 were collected from East Malling Research Station and from a farm in East Sutton. In 1949 and 1950 seeds, collected at East Malling, were taken from a Fuggle pollinated by a mosaic-carrier male and an Eastwell Golding pollinated by a mosaic-susceptible.

Seed treatment.

The fruit of the hop (Fig. 1a) is an achene with a persistent loose outer coat. The removal of this outer coat leaves the hard structure commonly known as the seed. At the distal end of the seed is an operculum (b). Beneath the testa, pointing up towards the operculum, is the radicle (c). Its position may be detected by the raised shoulder (d) at one side of the operculum.

The operculum is removed by the insertion of a needle (e) at its edge. Care must be taken to hold the seed in such a way that the operculum is uppermost and that the needle is pointing away from the radicle, in order to avoid injury to it. The slightest wound on the tip of the radicle adversely affects germination.

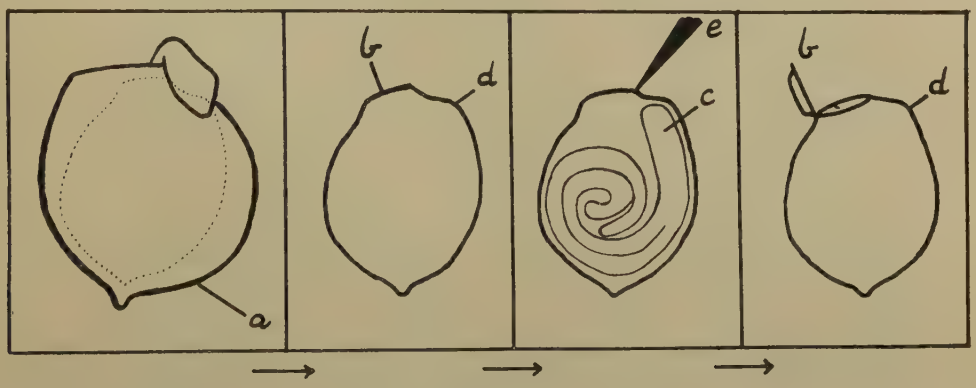


FIG. 1.

Diagram illustrating the structure of the hop fruit and its treatment. (*a*) Persistent loose outer coat ; (*b*) Operculum ; (*c*) Radicle ; (*d*) Raised shoulder ; (*e*) Needle.

During preliminary experiments carried out during December, 1947, seeds with the loose outer coat adhering to them went mouldy and failed to germinate when placed on moist blotting paper in the laboratory. Seeds from which the outer coat had been removed did not go mouldy as quickly and did on occasions germinate. In all subsequent work the outer coat was therefore removed by rubbing the seed between thumb and forefinger.

The treated seeds were germinated in John Innes compost in the dark, planting time being from February to March. In 1948 the seeds were kept in a warm frame at 60° F. during February, March and April, and in 1949 and 1950 they were kept in an unheated greenhouse. Germination was defined

as having taken place when the first pair of leaves appeared. Seeds which produced cotyledons only, and died before producing leaves, were not recorded as having germinated. In all cases final counts were taken at the end of May.

Results.

Early in 1948 an experiment was carried out to determine the effect on germination of (1) removal of the operculum, (2) freezing the seed for varying periods, (3) dipping the seeds in a 0·1 per cent solution of mercuric chloride in water. The results are summarized in Table I.

TABLE I.

NUMBER OF SEEDS GERMINATED OUT OF FIVE.

Origin of seed.	Days in refrigerator at 32° F.	0		16		34		43		57		72		Totals operculum removed *v.* entire seed.
	Treated with mercuric chloride (+) or untreated (—).	+	—	+	—	+	—	+	—	+	—	+	—	
East Malling	Operculum removed	2	3	0	1	0	2	3	2	3	2	3	0	21
	Entire Seeds	0	1	3	1	0	0	0	0	3	1	0	0	9
East Sutton	Operculum removed	4	4	1	3	5	4	2	5	3	5	4	4	44
	Entire seeds	4	3	3	3	0	1	0	3	2	2	2	2	25
	Effect of refrigeration totals ..	21		15		12		15		21		15		—

The data show that mercuric chloride application and freezing had no effect on germination, but that in general the removal of the operculum greatly increased germination. The relatively high germination of the seed from East Sutton is of interest. In this connection it may be noted that though the seeds from each source were Fuggles, the Malling hops contained an average of 10 small seeds, while the Sutton hops contained an average of four large ones ; the Malling hops were allowed to dry in the air before being stored indoors while the Sutton hops were kiln-dried finishing at a temperature of 140° F.

In 1949 and 1950 further tests were made to compare the germination of undried seeds with and without the removal of the operculum, both Golding and Fuggle seeds being used. In each case the germination was greatly improved by the removal of the operculum (see Fig. 2). In Table II the results for the three years are summarized.

TABLE II.

PERCENTAGE GERMINATION.

Seed treatment.	1948.	1949.		1950.	
	Fuggle.	Fuggle.	Golding.	Fuggle.	Golding.
Operculum removed ..	54	23·5	55	22·5	40
Entire seed	28	1·5	6	12	10

Summary.

Tests carried out over the last three years indicate that the germination of hop seed may be more than doubled by the removal of the operculum with a needle.

REFERENCE

SMITH, D. C. (1939). The influence of moisture and low temperature on the germination of hop seeds. *J. agric. Res.*, **58**, 369-81.

Fig. 2.

Relative germination of treated and untreated seeds, 1950.

A. Fuggle—entire seeds. B. Golding—entire seeds. C. Fuggle—operculum removed. D. Golding—operculum removed.

[face p. 140

ENTOMOLOGY

NOTES ON SOME INTERESTING INSECTS OBSERVED IN 1950

By A. M. MASSEE

1. Shot-hole Beetle (*Anisandrus dispar* Fabr.).

A number of Czar plums growing in a plantation at Ditton, Kent, were noted in July to be badly infested by the Shot-hole Beetle. This wood-boring beetle confined its depredations to the trunk and main branches, and since the insect was firmly established the damage caused by it proved quite serious. During hot, sunny weather the beetle may be seen running up and down the tree trunk during the months of May, June and July. During the rest of the year the beetle undergoes its transformations within the galleries made by the beetle grubs.

When an infestation starts in a plantation it is usual for only a few trees to be affected, but it should be noted that the insect is very active during the summer months, and may quickly spread to other trees, particularly those on which suitable egg-laying situations occur, such as cracks in the trunks and main branches.

As soon as trees are found to be infested by this beetle, it is advisable to examine all the trees in a plantation systematically ; those found to be infested should be dug up and burnt.

The Fruit Bark Beetle (*Scolytus rugulosus* Ratz.) was also noted boring into these plum trees, but the injury caused by this species was not as serious as that made by the Shot-hole Beetle.

2. Hop Root Weevil (*Epipolaeus caliginosus* Fabr.).

Since the Hop Root Weevil was first mentioned in these notes in 1937, and again in 1946, it has become clear that either it has extended its range in hop gardens, or that it is recognized more readily by hop growers ; it is reported by them more frequently than formerly. During April reports concerning this troublesome pest were received from Herefordshire, Worcestershire and Kent. The reports from Kent indicate that it is usually more troublesome in young hop gardens and to newly planted hop sets.

The grub stage of the weevil lives and feeds in galleries made in the roots, and there is little doubt that the insect is distributed from one garden to another in hop sets and plants used for gapping up in gardens. The weevil also occurs commonly in wooded areas ; for example, it is plentiful in the woods at Ham Street, near Ashford, and the adults may be found in the bundles of faggots left by the woodmen when cutting down the trees. The habits of the larvae under these conditions are not known.

The French Coleopterist, M. Edouard Perris, writing in 1877, states that the weevils occur under stones and on pathways, and that the larvae have been found in the galleries made by two species of wood boring weevils which infest pines.

3. The Long-horned Beetle (*Phymatodes testaceous* L.).

An interesting example of a Long-horned Beetle changing its host plant and infesting the cut-down trunks of pear trees, in preference to its normal host plant oak, was noted at Tonbridge in July. The larvae of this beetle were feeding in some numbers just under the bark, and the typical shallow cells and galleries made by the larvae were quite numerous.

Adult beetles of both the buff and blue forms were also common in July, an interesting fact since the normal flight period of the beetle is the latter part of May and June. It is possible that the unusual host plant chosen by the beetle may account for its late emergence.

There is little likelihood that this Longicorn will infest healthy pear trees, since the larva feeds just under the bark of newly cut-down trees ; it is not partial to trees which have been felled for three or four years.

4. Clay-coloured Weevil (*Otiorrhynchus singularis* L.).

The Clay-coloured Weevil must be regarded as a fruit pest of considerable importance. It attacks many kinds of fruits, and both adult and the larva are injurious. In the grub state it frequently

destroys the roots of strawberry and raspberry and sometimes devours the young rootlets of fruit-tree stocks. The adult is also troublesome since it destroys the scions of newly grafted trees and feeds on the shoots. The injury it causes to young hop vines is often considerable ; it has been noted in many hop gardens this spring.

Adult weevils were found causing serious injury to pear fruitlets growing in a commercial plantation at Danbury, Essex, early in June. As is usual the weevils worked at night, and damaged the fruitlets by gnawing pieces out of the flesh, at and near the stalks. Conference was more subject to attack, while other varieties were damaged to a lesser degree. The weevils also girdled the young growths of some of the pear trees, but the fruitlets were the chief attraction.

It may be noted that the adult weevil being wingless, a band of grease smeared around the trunk of the trees will stop the weevils gaining access to the main branches, and will prevent their causing damage.

5. Lesser Yellow Underwing (*Triphaena comes* Heub.).

The Lesser Yellow Underwing is a very common British moth which is on the wing in July and August. It normally lays its eggs on low-growing plants, and the caterpillars feed intermittently from September to April.

Batches of eggs found on the undersides of apple, peach and raspberry leaves were brought into the laboratory in mid-August, and these proved to be the ova of the Lesser Yellow Underwing. These are round, strongly ribbed, reticulated, brownish in colour and clouded with a darker tint at the apex. On hatching, the larvae fed readily on apple, peach and raspberry foliage ; the warmth of the laboratory induced the larvae to feed continuously and all pupated by the end of November. The mature larva is greenish-brown with three longitudinal yellowish lines on the back, the central one being edged with black, the others with darkish oblong marks. The spiracles are white with a yellowish longitudinal line just below them. The head is dark brown and mottled. The moths emerged from 19th January onwards in the laboratory, six months earlier than is normal under natural conditions.

It is curious that this moth should choose to lay its eggs on the foliage of fruit trees, when its normal hosts are various species of low-growing plants, all of which are plentiful in the district. It was evident from the number of egg batches noted on fruit that the selection was not an isolated incidence, several different females of the species being concerned.

The Lesser Yellow Underwing is not regarded as a potential pest of fruit, but its occurrence on three kinds of cultivated fruits is worthy of record.

6. Wood Leopard Moth (*Zeuyera pyrina* L.).

Reports concerning the injury caused by the larva of the Wood Leopard have come in every year from most fruitgrowing districts, and a brief account of the damage caused by the larva was outlined in these notes in 1935. Since that time the Wood Leopard has become much more numerous in young fruit plantations, and it must now be regarded as a serious pest. For example, it is now very widespread in the Maidstone district of Kent, and it is common in Essex and at Wisbech.

The moth emerges in May, June and July and it lays spherical yellow eggs singly in cracks and wounds of the shoots and main branches, and even in the main stems of maiden and two-year-old trees. The moth usually selects young trees for egg laying purposes, and those over fifteen years old are rarely attacked. The larva bores into shoots and branches of from one inch to four inches in diameter, and does not infest the very large limbs. It invariably bores upwards from the point of entry, and when fully grown the caterpillar has tunnelled out a gallery from six to eight inches long. The larval life may extend over three years, but in the laboratory this period may be considerably reduced. The fruit varieties subject to attack are apple, pear, plum, cherry, almond, nut, walnut, and quince. Wild hosts include maple, sycamore, hawthorn, ash, sallow, lilac and elm. In the Maidstone district horse-chestnut is a favourite host.

Unfortunately it is not possible to detect the branch in which the larva is feeding, at least in the early stages of an attack, and in young orchards where the insect is suspected to be at work it is advisable to bend over each stem ; those containing a gallery will break off at the point of entry of the larva and split upwards. Older borings may be detected by the pile of frass at the base of the stem of the tree and also by the discoloured bark of the affected shoot.

7. Codling Moth (*Ernarmonia pommella* L.).

In common with many of the more important fruit pests the Codling Moth has peak years when it is very abundant. Such years were noted in 1911, and again in 1921 and 1922. More recently, bad

infestations were recorded in 1934-5, while Codling Moth has been very prevalent during 1949-50. There are indications that it will again be plentiful next year.

The Codling Moth is widespread throughout the fruitgrowing districts of England, Wales and Scotland, and infestations may be seen in the private garden and smallholding in addition to the commercial orchard.

During a visit to the New Forest district of Hampshire during the latter part of August bad infestations of Codling were noted on isolated crab apple trees growing in remote parts of the New Forest near Brockenhurst, and also in the Bratley Beeches district. Adults of the Apple Blossom Weevil were also present on the same trees. The fact that these isolated trees were infested with Codling Moth larvae is of interest, because the same trees were examined in 1949 and were found not to be infected. This presents a clear illustration of how readily certain kinds of insects find their natural hosts, even where the latter are growing in remote situations, far away from gardens and commercial plantations.

Codling Moth larvae were also found infesting quince fruits of the variety *Chaenomeles cathayensis*, growing in the private garden of Mr. N. H. Grubb at Leybourne, Kent.

8. Bud Moth (*Spilonota ocellana* Shiff.).

The Bud Moth proved very troublesome in several orchards in the Chelmsford district during May and further reports were received from Wisbech and Kent in April and May.

Although the Bud Moth is closely allied to the Tortricid Moths affecting fruit, it behaves in a very different manner to those species which feed on the fruit surfaces. The Bud Moth causes serious loss by feeding within the potential fruit buds, and on some trees a high percentage may be infested by the larvae. The latter can readily be recognized by the grower in the spring, if a careful examination of the buds is made when new growths begin to develop. Infested buds fail to expand and the shoots appear to be partially withered. On inspection a small reddish-brown caterpillar with a black head will be seen inside the bud. About the time of flowering the larva leaves the bud and starts to feed on the leaves. It draws several leaves together by means of silken threads, and it lives and feeds within this protective canopy of leaves. On occasions it may come out and feed on the young leaves during the day time, returning again at night. The chrysalis is spun up amongst the foliage, and the moth emerges in June and July.

The fact that the larva lives inside the bud during the spring makes control measures very difficult, but the inclusion of 5 lb. DDT (20 per cent wettable powder) in the "green cluster" lime-sulphur spray materially reduces the Bud Moth infestation of an orchard.

9. Apple Clearwing (*Sesia myopaeformis* Bork.).

Several reports concerning the damage caused by the Apple Clearwing came from Cambridgeshire in May and June. The caterpillar of this fly-like moth cannot be regarded as an important apple pest since it mainly occurs on old and neglected trees. A severe infestation was noted at Hoo, near Rochester, Kent, in 1938, and was referred to in these notes. It has not again been found commonly in commercial orchards until this year.

The caterpillar feeds on the tissue just beneath the bark, which peels off readily when a number of caterpillars are at work. It is a dull yellowish-white, with a brown head, and is about half-an-inch long when fully developed. The larvae received from Wisbech and Cambridge pupated from 13th June onwards, and the adults emerged at the end of the month.

Apple Clearwing attacks are frequently confined to a few trees, and when injury by this insect is suspected it is advisable to examine carefully the tree trunks in April or May, and to remove or scrape off all the loose bark where the larvae are feeding. A swan-necked onion hoe proves an ideal tool for the purpose. The trunks of infested trees should be treated with a DDT preparation. There is no need to apply the DDT to the branches or leaves, since the larvae confine their depredations to the main trunk.

10. Fruit-Surface-eating Tortrix (*Tortrix diversana* Hueb.).

A number of species of Tortricid moths occur on cultivated fruits, and one of them, *Tortrix diversana* Hueb., is found on apple every year, but it is not usually common enough to cause very much harm. A number of severe infestations were, however, noted in East Kent this year, especially in the Faversham and Teynham districts.

The moth of this species is on the wing in June or July. The larva is very variable in appearance. It may be green with a darker dorsal line, with raised yellow dots, and head and dorsal plates

red-brown ; alternatively, it may be of a grey-green colour without a dorsal line, with raised black dots bordered with yellow and head dark brown.

The larva feeds on the flesh of the apple in July and August, before going into hibernation.

On many occasions the larvae were observed to nibble large pieces out of the flesh the size of a sixpence, and in several examples the cavity excavated was half-an-inch deep. The larva is extremely active and moves readily from one fruit tree to another ; thus in the course of a few days, a large number of fruitlets may be disfigured. Even the smallest injuries on the fruitlets are serious since they allow of the entry of the Brown Rot fungus. The larva is very partial to soft-fleshed varieties such as Beauty of Bath ; Bramley's Seedling and Newton Wonder were not badly infested.

The larva overwinters in a silken cocoon or in a rolled-up dead leaf on the tree. It becomes active again about April and feeds on the foliage, pupation taking place in May. The pupa is spun up amongst the leaves.

The caterpillar feeds on a variety of plants. The following hosts have been noted : alder, aspen, birch, blackthorn, buckthorn, elm, hawthorn, honeysuckle, poplar, sallow and willow.

11. Hawthorn Leaf Miner (*Lithocolletis* sp.).

The damage caused by the larva of the Apple Leaf Miner (*Lyonetia clerkella* L.) is frequently quite serious, and the typical mining operations within the leaf, caused by the larva of this Tineid moth, show up conspicuously on young apple trees and stocks growing in nursery beds. In this country, however, it is not considered of economic importance. It is interesting to record similar damage caused by the larva of a second species of Tineid moth, the Hawthorn Leaf Miner. This was discovered mining foliage of Lane's Prince Albert at East Malling. The infested trees were adjacent to a public right of way, the other side of which consisted of a chestnut wood studded with various other trees and bushes. A number of hawthorn bushes were growing here and there near the edge of the wood, and the leaves of these were also infested. There is little doubt that the leaf miner infesting both hawthorn and apple were the same species, and that the hawthorn was the source of the outbreak on apple. The species concerned has not been determined with certainty, but it is likely to be *Lithocolletis corylifoliella* Haw., which was recognized nearly one hundred years ago as being associated with hawthorn and species of *Malus*.

The Hawthorn Leaf Miner is not an important pest on apple, but since a number of insects have been known to change their host plants in a comparatively short time, any insect establishing itself on fruit is worthy of record. This species produces characteristic mines on the upper surface of the leaf, the epidermis being raised, forming a conspicuous oblong blotch. There are two generations, the first occurring in July and the second in October and November. The larva is pale yellowish with green between the segments. The head and mouth parts are brownish and the thoracid plate dark ; the third segment is broader than the second and fourth.

A closely allied species, *Lithocolletis coryli* Nic., mines the upper surfaces of the leaves of cultivated nuts, and is plentiful in some seasons. Like the hawthorn species it is not regarded as of economic importance.

12. Apple Sawfly (*Hoplocampa testudinea* Klug).

The Apple Sawfly was again very prevalent during 1950 in many of the main fruitgrowing districts of Kent, Essex and Sussex, and some important observations concerning this serious pest have been made. One notable fact was the prevalence of sawfly on culinary varieties, such as Bramley's Seedling, Newton Wonder and Early Victoria. Severe infestations were noted on these varieties in June at Hoo, and Marden, Kent, and near Rye, East Sussex.

Another unusual observation, noted in the Canterbury district in the third week of June, was the marked variation of infestation of the same variety, Cox's Orange Pippin in various grass orchards situated in the same locality. In some orchards the intensity of attack was estimated to be as high as 50 per cent while in others very few fruits were infested. Incidentally, Worcester Pearmain growing close at hand was always badly infested.

In commercial orchards the synthetic insecticide benzene hexachloride (BHC) was tried for the first time, the application being made five to ten days after petal-fall. The formula of the spray most frequently used was : 2 lb. benzene hexachloride (50 per cent dispersible powder), lime-sulphur $\frac{3}{4}$-1 gallon, water 99 gallons. Very satisfactory reports of sawfly control were received from many farms where BHC was used. This is the more encouraging as only one application had been made on most farms.

13. Pear Sawfly (*Hoplocampa brevis* Klug).

Further observations have been made in the pear plantations where the outbreak of Pear Sawfly was discovered at a fruit farm at Hoo, near Rochester, Kent, last year and reported in these notes.

The pest was not discovered soon enough last season to enable the grower to eradicate it, but very good control was obtained by means of either a derris and nicotine insecticide or derris and parathion.

The plantations were visited regularly this spring from the start of the blossom period until after petal-fall. The first adult sawflies were noted in the open flowers of Conference on 17th April, a very cold and windy day. A week later they were collected from the blossoms of several varieties. On 28th April an examination of Conference blossoms was made for eggs. Within 307 blossoms dissected, eggs were found in 104. Of these, 75 blooms contained one egg each, 13 housed two eggs, while a single blossom contained three eggs. The embryos proved to be in an advanced state of development, the ova being swollen considerably and the eye spot of the larva visible in many of them. The average size of 25 eggs was $0 \cdot 8 \times 0 \cdot 3$ mm.

A survey was undertaken of a thirty-year-old bush plantation containing six varieties ; Conference proved to be most susceptible to attack, while Beurré Bosc, Souvenir de Congres, Dr. Jules Guyot and Clapp's Favourite were infested to a lesser extent. Catillac was markedly resistant, since none of the fruits was found to be infested. In an adjacent plantation Williams' Bon Chrétien and Marguerite Marillat were affected, as were a number of thirty-year-old standard pears of the varieties Conference, Fertility and Dr. Jules Guyot.

Both plantations were sprayed with 0·01 per cent parathion, the first application being made when the first larvae were observed to hatch out. A second application followed one week later at the same strength. Observations made some days later indicated that the larvae were killed by the treatment, and that a satisfactory control of the pest had been obtained. A new outbreak was noted in a standard pear plantation about three miles away from the original outbreak at Hoo ; thus it is imperative that fruitgrowers continue to watch their pear plantations assiduously each spring, in order that any suspected infestation of Pear Sawfly can be examined by an expert, and that appropriate measures be taken when necessary to wipe out the pest.

14. Pear and Cherry Slugworm (*Caliroa cerasi* L.).

The larva of the Pear and Cherry Slugworm is a familiar sight on the leaves in many Kentish orchards, and although widespread, it cannot be considered a serious fruit pest. Several bad infestations of this sawfly were noted in plum orchards in the Cranbrook area of Kent in July. It is significant that the attacks were confined to plum, which is not the usual host, although the more normal hosts, pear and cherry, were both growing in the vicinity.

The Pear and Cherry Slugworm has two generations a year, and in some seasons there is a partial third. The outbreaks at Cranbrook were of the second generation. The slug-like larva feeds on the upper surfaces of the leaves, eating away the epidermis, and causing the leaves to become blotched ; they are frequently completely skeletonized. Injury seems to be more severe on plums than on cherry or pear. The winter is spent in the caterpillar stage, contained in a cocoon in the soil.

Fortunately this sawfly is very readily controlled by spraying or dusting with nicotine, derris, lead arsenate or pyrethrum, only one application being necessary.

15. Woolly Aphid Parasite (*Aphelinus mali* Hald.).

The Woolly Aphid Parasite is well established and very widely distributed in the Eastern Counties and the South-East of England. In fact it has become very abundant in many Essex plantations, where it has eradicated completely Woolly Aphids in a number of commercial orchards.

In most years the parasite begins to emerge in the latter part of May and in June, but for some reason not explained emergence began at the end of April this year. Hatching at this early date was noted in both Kent and Essex orchards.

It has also been observed that increases of Woolly Aphid populations occur in orchards which have received one or more applications of DDT or benzene hexachloride after the blossom period. This increase is explained by the fact that both insecticides destroy the parasites of the Aphid. Again, it is unfortunate, but nevertheless true, that the parasites are also eradicated in orchards where parathion is applied as a post-blossom spray to control The Fruit Tree Red Spider Mite.

16. Green Apple Aphid (*Aphis pomi* Deg.).

Although the Green Apple Aphid has not been plentiful in nursery beds and on young apple trees during recent years, a nucleus of the species is ever present, awaiting the opportunity to build up its populations when suitable conditions occur.

During the first week of March a number of tom-tits were seen " working " the buds of the new growths of a medlar tree at East Malling. A more thorough inspection showed that these small birds were feeding on the newly emerged colonies of the Green Apple Aphid. The aphids continued to hatch out until the end of March, and by early April were plentiful on the one-year-wood. It is curious that the aphids hatched out so early in the year, since the normal time of emergence is from the middle of April onwards. This early hatch seemed to be general in the district since the same species was noted in March on young apple trees, on nursery stocks and also on wild crab apples growing in Oaken Wood, East Malling.

The same phenomenon was noted in Kent by the late Professor F. V. Theobald, who specifically mentioned an early hatch of the Green Apple Aphid as long ago as 1894.

17. Oat-Apple Aphid (*Rhopalosiphum insurtum* Wlk.).

The Oat-Apple Aphid was very prevalent in many Kentish apple orchards in May and June, 1949, but it was decidedly scarce during the spring months of the following year. During September and October, however, large numbers were returning to apple from their summer hosts, various species of grasses, and consequently very high egg populations of this aphid are present in many Kent orchards. Particularly heavy infestations have been noted in the East Farleigh, Marden and Maidstone districts of Kent.

A likely explanation of the high egg population this autumn is that the wet July, August and September encouraged the succulent growths of the various grasses upon which the aphid feeds during this period of the year. This condition of plant growth induced large colonies of aphids to build up, and in due time the winged forms returned to apple to lay their complement of eggs on the spurs and in the cracks and crevices of the branches. If the months of July, August and September had been hot and dry, as in the previous year, it is probable that the aphid populations would have been very much smaller, as was indeed the case in 1949.

18. Hop-damson Aphid (*Phorodon humuli* Schr.).

The Hop-damson Aphid behaved in a somewhat unusual manner during the summer months. It started to return to the hop gardens from sloe, damson and plum during the middle of May, and high populations soon built up. In spite of two or more applications of parathion, TEPP, or schradan, the aphids persisted in many hop gardens ; in various parts of Kent high populations were still present during the latter part of July when the hops had reached the burr stage. The aphids continued to breed on the vines throughout August and September, living and feeding mainly within the hop cones, and frequently causing considerable injury by checking the growth of the fruits. In some instances the damage caused by the depredations of the Hop-damson Aphid, aggravated by the unkindly weather prevailing at picking time, was so severe that portions of several gardens in East Kent were not harvested.

During the latter part of September and in October the winged aphids returned to sloe, damson and plum, and at the present time very high egg populations may be found on plums and damsons throughout Kent.

19. Peach-Potato Aphid (*Myzus persicae* Sulz.).

The Peach-Potato Aphid was very prevalent in June, and fan-trained trees growing against the walls were subject to heavy attack. This species may be very troublesome when present in large numbers, since severe leaf-curl results and the new growths are badly stunted. A noteworthy observation was made concerning this species. A number of trees were very badly attacked, and all the leaves were curled, yet in spite of this the aphid did not infest the fruits, which in due course developed normally and retained their flavour.

The Peach-Potato Aphid was noted in many parts of Kent, the worst attacks occurring in the West Farleigh district. A small plantation growing near Danbury, Essex, was also affected by this aphid, with the result that a high egg population built up in the autumn.

A number of species of aphids infest peach, but why they are not present each year, even in small numbers, remains a mystery. These infestations are intermittent, occurring only once in five or six seasons.

20. Pear Aleyrodes.

A very severe leaf infection by a species of *Aleyrodes* or scale, was reported from a private garden at Beckenham, Kent, in September. All the foliage on a large fifty-year-old standard pear tree was

blackened by the secretion of the insects, and the dead immature scales were plentiful on the upper surface of the leaves.

This is the first record of a species of *Aleyrodes* infesting cultivated pear. The species concerned has not been determined, but it is hoped to obtain further material for the purpose next season.

21. Strawberry Red Spider (*Tetranychus telarius* L.).

Adult females of the Strawberry Red Spider were very active early in the season, and they were observed laying their eggs on the under surfaces of the leaves during the last week of March. In one strawberry field near Charing, Kent, egg laying was general by the first week of April.

Another closely allied species, the Hop Red Spider, also started laying eggs very early in the season. Eggs were being laid on the leaves of wild hops growing in the hedgerows at the Research Station during the second week of March, while in the hop gardens, oviposition was prevalent early in April.

Generally speaking neither the Strawberry Red Spider nor the Hop Red Spider were important pests during the year, the wet weather of July, August and September preventing a rapid increase of either species.

22. Fruit Tree Red Spider Mite (*Metatetranychus ulmi* Koch).

Pear has been recognized as a secondary host plant of the Fruit Tree Red Spider Mite for many years, but usually it causes little or no damage to this fruit. A very bad attack of mite occurred on Catillac Pear during the summer months at Keston, Kent. A number of severe infestations have been seen in previous years, but this outbreak was much more serious. The foliage of the trees started to bronze in July and by the latter part of August most of the leaves were of a silvery-brown colour. The fruit, however, did not appear to be affected by the attack.

The trees were examined again early in October, and it was discovered that no winter eggs had been laid on the spurs or branches. Indeed, mites and the immature forms on the leaves were also few in number. More detailed observations indicated that the mites had dispersed from the pears to Cox's Orange Pippin growing near at hand, and that on the latter trees the mite and egg populations were abnormally high. It would appear that the mites had dispersed from pear to apple during the latter part of August and in September, at the time when the leaves of Catillac became leathery and ceased to function normally.

The dispersal of mites from the leaves of trees no longer meeting their requirements has been noted many times on apple, but this is the first occasion that the same phenomenon has been seen on pear.

Summary.

An account is given of the interesting insects and mites noted in 1950. Special mention is made of Pear Sawfly, a pest first recorded in these notes last season. Reference is also made to the high egg populations of certain fruit aphids this autumn.

A METHOD FOR THE ESTIMATION OF INSECT POPULATIONS ON FRUIT TREES

By ELSIE COLLYER

Introduction.

When the study of predacious insects on fruit trees was started in Essex in 1946 no accurate method was available for estimation of their populations in the field. Listo, Listo and Kanervo (1939) relied on visual examinations of certain parts of the tree over a fixed period of time. Active insects may be assessed by tapping the branches of the tree, and catching the falling insects in a beating tray. This technique was used by Dicker (1946) and Lord (1949) ; it has been used extensively in this investigation, where it has given a valuable indication of the fauna present on the trees. Four branches of each tree are tapped in a uniform manner, and all insects alighting on the beating tray are counted. It would seem that figures arrived at in this way from various trees and orchards are comparable, if recording is done during similar weather conditions. On the other hand, comparison of the numbers of different species and instars is probably not valid, as their activity and habits differ widely. Other disadvantages inherent in this method are that the results depend to a large extent on the operator and the weather conditions and that the operation is very difficult to carry out when the fruit is still on the tree, falling fruit disturbing the insects which have alighted on the tray. It was therefore considered necessary to devise a more reliable method for the accurate estimation of insect populations.

Method.

During 1949 preliminary work was carried out with an apparatus specially designed for the purpose by Mr. W. E. Edmonton of Messrs. Buggé's Insecticides Ltd. The aim was to enclose the whole tree rapidly in a cloud of insecticide which would knock down the insects before they had a chance to escape. The method proved to be effective, and after further modifications was used regularly in 1950.

The Apparatus.

Mr. Edmonton describes the atomiser as follows : " In designing the apparatus the aim was to envelop the tree in a uniform mist of insecticide. This was achieved by means of bottle atomisers (Fig. 1) connected by rubber tubing to a distributing unit fed by pressure from a cylinder of compressed air or nitrogen (Fig. 2). The complete unit consists of : 6 bottle atomisers, six 9 foot lengths of high pressure rubber tubing, 1 pressure distributor, 1 cylinder of compressed air, 1 pressure reducing valve and gauge.

" The bottle atomiser consists of an amber-coloured glass bottle having a wide neck with a screw thread that will take the screw-on metal cap, carrying the atomising unit.

" The atomising nozzle consists of an air chamber surrounding a small jet, which projects through an adjustable cone. The jet is situated at the top of a tube leading from the liquid insecticide in the bottle.

" The compressed air is fed to the air chamber through a brass union and a duct drilled through the side of the body. The gap between the centre jet and the orifice of the cone can be adjusted by screwing the cone in or out ; the cone can then be locked by a lock-nut, which can itself be secured by a small grub-screw. This adjustment is critical and requires careful manipulation.

" In the atomising operation compressed air passes into the air chamber in the cone and as it rushes out of the orifice at the top sucks the liquid insecticide from the bottle up through the centre tube to the jet. Here the liquid meets the current of air in the orifice of the cone and is broken up into tiny droplets which are carried upwards with the air stream. If the gap between the jet and the orifice of the cone is too wide, the vacuum produced is insufficient to suck up the liquid from the bottle. On the other hand, if the centre tube projects too far above the orifice of the cone, suction is again lost and the atomiser fails to function.

" The pressure distributor is a 3 foot length of two inch metal tube sealed at one end and fitted with six brass nipples at 4 inch intervals along the tube. These brass nipples are connected to $\frac{1}{4}$ inch brass unions which are forced into 9 foot lengths of rubber tubing and secured by means of No. ' o ' Jubilee

Clips. The other end of the rubber tubing has a similar type of union which makes an airtight connection between the bottle atomisers and the compressed air distributor. The open end of the metal tube is connected to the reducing valve by rubber tubing secured by Jubilee Clips.

" The compressed air is supplied from a cylinder which has a reducing valve attached to ensure a constant flow of air at the required pressure. The reducing valve is provided with two gauges, one of which indicates the pressure supplied to the distributor and the other indicates the quantity of compressed air in the cylinder.

The insecticide.

" The insecticide consists of pyrethrum extract in a mixture of mineral oils and contains 0·3 per cent of total pyrethrins. Advantage is taken of the fact that the active principles of pyrethrum (the pyrethrins) are intensely irritating to most insects and will also produce a rapid paralysis of the muscular nervous system, causing the insects to lose control of their legs and topple off the trees. A rapid narcosis follows the paralysis and, when a lethal dose of the pyrethrins has been received by the

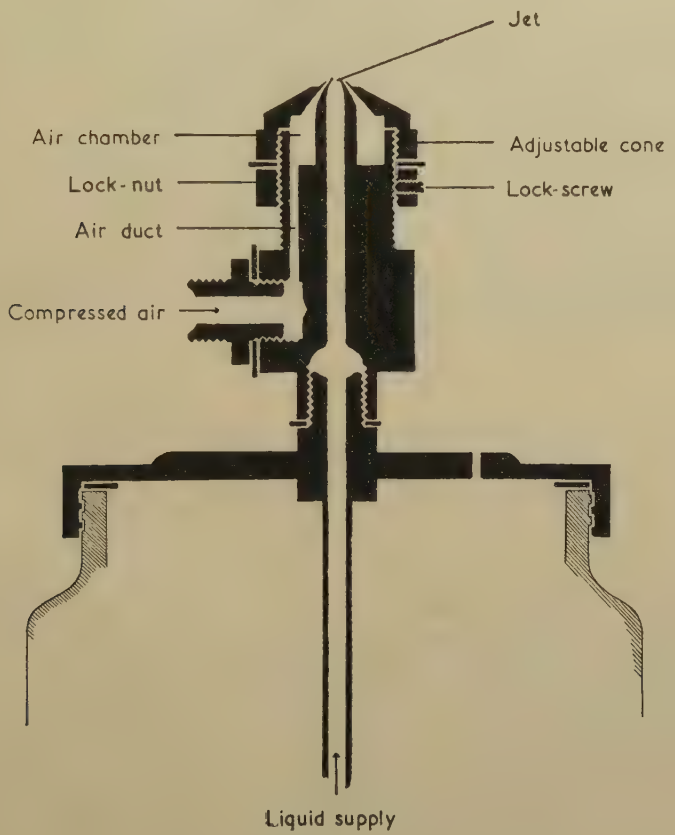


FIG. 1.
Detail of the atomising bottle.

insect, death quickly supervenes. If, however, an insect has only received a sub-lethal dose this narcosis wears off and the insect recovers.

" To decide in what medium the pyrethrins could best be atomised, due consideration had to be given to the physical characteristics of the finished insecticide. If the insecticide is too viscous it requires a very high pressure to break it up into tiny particles and if the particles are coarse they settle too quickly and the fog effect is lost. With a solvent that is too volatile, rapid evaporation takes place and the minute particles of pyrethrum extract that are left behind do not seem to affect the insects so readily as with a less volatile medium. The medium finally selected consists of a mixture of 75 per cent of a light hydrocarbon oil and 25 per cent of a heavy hydrocarbon oil. The two oils have the following specifications :—Light oil : specific gravity 0·78 ; viscosity (Redwood) 35 seconds ; unsulphonatable

residue 98 per cent. Heavy oil: specific gravity 0·89; viscosity (Redwood) 118 seconds; unsulphonatable residue 99 per cent.

"The insecticide should not be exposed to bright sunlight, as the pyrethrins are readily decomposed under such conditions with a rapid loss of toxicity. It is for this reason that amber-coloured bottles are used as containers in the atomising unit."

Screens.

When used in the field it was apparent that screens were necessary to keep the cloud of insecticide in the tree for a sufficient length of time; even on relatively calm days the air movements dispersed the cloud very rapidly, and usually prevented it enveloping one side of the tree. The screens used were those described by Austin and Massee (1947) for the prevention of spray drift; two of these screens completely enclose an average sized tree, being held by six men (Fig. 3).

Groundsheets.

During 1949, a 9 feet square khaki hessian groundsheet was used under each tree to catch the falling insects. During the course of the season's experiments this type of sheet was found to be inadequate in several ways: a slight breeze sufficed to blow dead insects from the sheet; many insects which revived were able to escape from the sheet at the centre where it fitted round the tree trunk; the coarse mesh of the hessian made collection of the smaller insects difficult; the khaki colour was not suitable as many insects, particularly the greenish Mirids, were difficult to see. A new sheet was therefore used in 1950 (Fig. 4). The sheet is 12 feet square, and made of black Indian cotton duck*; the material is of finer mesh than the hessian of the original sheets. A 9 inch high collar was introduced at the centre of the sheet to prevent escape of insects; it ties round the tree trunk and can thus be adapted to a tree of any size. Around the edge of the sheet is a 9 inch high border of the same material; it is kept upright by 2 foot long metal stakes which pass through a series of sleeves in the border into the ground, at the same time keeping the whole sheet taut. At one side is an opening to allow the sheet to be placed round the tree, a substantial overlap of material being provided.

Use in the orchard.

The trees used for insect population estimates by this method have been fifteen-year-old apple trees, variety Worcester Pearmain; with trees of this size the span of the branches is usually within the 12 feet square of the groundsheet. Complications might arise with the use of considerably larger trees, as screening would be difficult and the cloud of insecticide might not penetrate through the tree.

Experience has shown that for the estimation of the fauna of six trees a labour force of eight people is needed for approximately one and a half hours to apply the pyrethrum. After this two people are fully occupied in collecting insects for the remainder of the day, and one or two days are then occupied in sorting and counting the collection.

Many insects are affected almost immediately by the insecticidal mist and a large percentage come down within half an hour; some, however, fall several hours later. Revival of the more resistant insects may occur within 1½ to 2 hours, so that a collection soon after spraying is necessary in addition to one several hours later. It was observed, especially on warm and calm days, that a few winged insects flew from the top of the tree before being enveloped in the cloud of pyrethrum. Apart from this slight loss, all the relatively large and active insect species are obtained. Inactive larvae of such species as *Stethorus punctillum* (Wei.) and *Oligota flavicornis* (Boisd.) remain attached to the leaf surface, and the predaceous Laelaptid mites are too small to be recovered. It was observed that some of the active stages of the Fruit Tree Red Spider Mite were killed, especially those on the lower branches. As a large percentage of the insect population is removed, and some of the mites killed, it is obvious that if later observations are to be made, this method of estimation must not be used on too many trees in one area, as otherwise the population balance may be completely changed.

Some field results.

The method has provided valuable information concerning the fauna of fruit trees; one example is given here to show the type of problem for which the apparatus is being used.

On experimental plots where various sprays are being tested against the summer stages of the Fruit Tree Red Spider Mite one tree from each treatment has been taken at approximately fortnightly intervals, and the total insect population counted. In 1949 the sprays were applied on 1st June and

* 18 oz. per square yard.

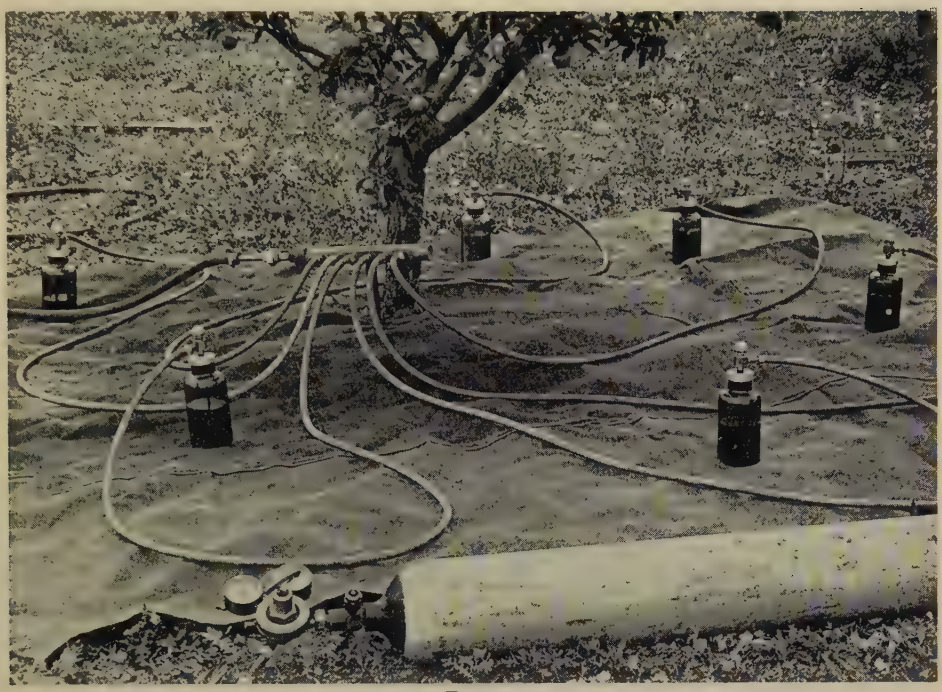


Fig. 2.
The atomising apparatus complete.

Fig. 3.
Method of screening, showing original hessian groundsheets, 1949.

[face p. 150

FIG. 4.
The modified groundsheet, 1950.

the figures given in Table I were obtained on 8th July ; the most numerous predator of the mite was *Blepharidopterus angulatus* (Fall.) (Collyer, 1949) ; numbers of this species only are given, although counts of all species were made.

TABLE I.

NUMBERS OF *Blepharidopterus angulatus* (FALL.) COLLECTED AFTER VARIOUS SPRAY TREATMENTS.

Treatments. Applied on 1st June.	Number from one tree on 8th July.
Parathion 0·06 per cent	1
DCPM: bis(*p*-chlorphenoxy) methane 0·09 per cent	1,285
Control	1,062

The treatments were applied before many *Blepharidopterus angulatus* (Fall.) nymphs had hatched. Parathion killed all the nymphs which hatched between that time and 8th July ; it therefore showed a residual toxicity towards this species of over five weeks, as nymphs were still hatching at that date on trees not treated with parathion. The DCPM had no residual effect, although it killed the active nymphs at the time of application ; their numbers on 8th July did not differ appreciably from the control. Counts made throughout the summer give a clear picture of the general fluctuations in the populations of various insects.

Although now in regular use, the apparatus is not considered to be perfected ; the number of trees that can be treated at one time is small, owing to the considerable time expended on collection, identification and counting. It is hoped that further experience will lead to the development of sampling methods which will permit of speedier estimation of the numbers of insects present.

Acknowledgements.

The writer is indebted to Messrs. Buggé's Insecticides Ltd., of Sittingbourne, Kent, for their co-operation in this work, and especially to Mr. W. E. Edmonton for designing the apparatus.

Summary.

A method for the accurate estimation of insect populations on apple trees is described ; pyrethrum in oil is atomised to form a cloud which envelops the tree and causes a rapid knock-down of insects, which can then be collected from sheets beneath the tree.

REFERENCES

AUSTIN, M. D. and MASSEE, A. M. (1947). Investigations on the control of the Fruit Tree Red Spider Mite (*Metatetranychus ulmi* Koch) during the dormant season. *J. Pomol.*, **23**, 227-53.

COLLYER, E. (1949). The predator aspect of the Fruit Tree Red Spider problem. *Rep. E. Malling Res. Sta. for 1948*, 108-10.

DICKER, G. H. L. (1946). The biology of the Apple Blossom Weevil, *Anthonomus pomorum* L. *J. Pomol.*, **22**, 140-52.

LISTO, J., LISTO, E. M. and KANERVO, V. (1939). Tutkimuksia hedelmäpuupunkista (*Paratetranychus pilosus* C. & F.). *Valt. Maatalousk. Julk.*, **99**.

LORD, F. T. (1949). The influence of spray programs on the fauna of apple orchards in Nova Scotia. III. Mites and their predators. *Canad. Ent.*, **81**, No. 8.

DAMAGE TO APPLE LEAVES BY THE FRUIT TREE RED SPIDER MITE, *METATETRANYCHUS ULMI* (KOCH)

By CATHERINE A. BLAIR*

Introduction.

In the extensive literature on the Fruit Tree Red Spider Mite *Metatetranychus ulmi* (Koch), there are many references to the characteristic external appearance of infested apple leaves, but only two writers, Trägårdh (1915) and Geijskes (1938), refer to and illustrate the internal damage caused to the leaves by the mite's feeding. It was therefore decided to round off the work on the life history and habits of this species by a study of the pest-host relationship.

The mouth-parts of the allied mite *Tetranychus telarius* (L.) were described and figured by Blauvelt (1945). They consist of a ventral portion, the rostrum, with a median U-shaped groove in which moves the dorsal mandibular plate. In puncturing the leaf tissue during feeding the stylets are activated by a rapid in and out movement of the mandibular plate as well as by muscles attached to the stylets.

External symptoms of damage.

The Fruit Tree Red Spider Mite usually feeds on the under surface of the leaf, inserting its fine needle-like stylets through the epidermis and withdrawing the plant juices. Much internal damage may be caused before any sign of external damage is evident. One mite feeding on an apple leaf for thirty minutes will produce detectable leaf damage internally and this can be demonstrated by dipping the leaves in Carney's Fluid and then fixing them in Bouin's Fixative, when the feeding areas of the mite show up as red spots.

The first leaves of the tree to show damage externally are those in the centre of the tree ; it is on these leaves that the majority of larvae hatching from the winter eggs are found.

As the damage to a leaf increases in severity, the external symptoms change. A faint yellowish speckling along the mid and lateral veins first appears, followed by a dull greyish colour extending over the whole of the leaf. This changes to bronze, followed by silver-grey in the case of a very severe attack.

Internal damage.

The mite feeding on the lower surface of the leaf forces its stylets through the lower epidermis of the leaf, through the spongy mesophyll tissue, and penetrates a cell of the palisade tissue. Only the cell which is actually penetrated by the stylets is damaged, there being no evidence of effects upon adjacent cells. The chloroplasts disappear from the cell, and the contents coagulate, forming an amber-coloured mass at one end of the cell. In very badly damaged leaves, the complete contents of many of the palisade cells may disappear.

The changes occurring in the palisade tissue are visible through the thin upper epidermis. The faint speckling is produced when there are only a few amber-coloured cells, the bronze coloration when there are many areas of brownish cells, and the silver when the cells of the palisade tissue are empty of contents and filled with air.

Cells of the spongy mesophyll may be affected, but only occasionally as they are relatively few in number and widely scattered. No attempt by the mite to penetrate the vascular bundle has been observed. In comparing sections of damaged and undamaged leaves it is very noticeable that the former show many flattened epidermal cells on the lower surface of the leaf. It would appear that these are affected by the mite while penetrating to the overlying tissue.

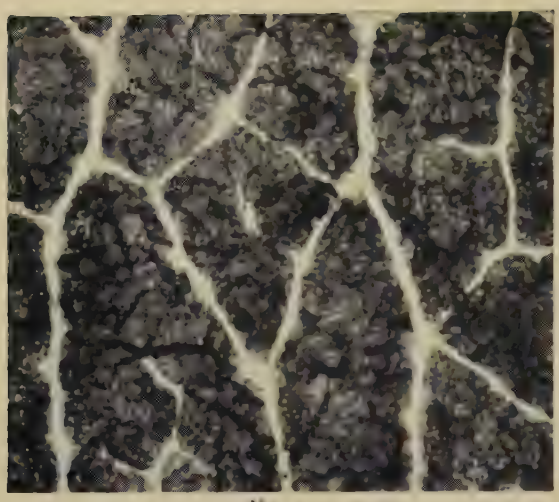
Leaves which have not been affected appear a dark blue when subjected to the iodine test for starch, while damaged leaves, according to the severity of the attack, give fainter colours down to a pale blue speckling. Sections of such leaves show that cells which have shrunk and whose contents are massed in the ends of the cell contain no starch. In less damaged cells the starch grains are free, the chloroplasts having been broken down. In undamaged cells the starch grains lie in groups within the chloroplast.

* Member of the A.R.C.-Pettar-Ace Red Spider Investigation.

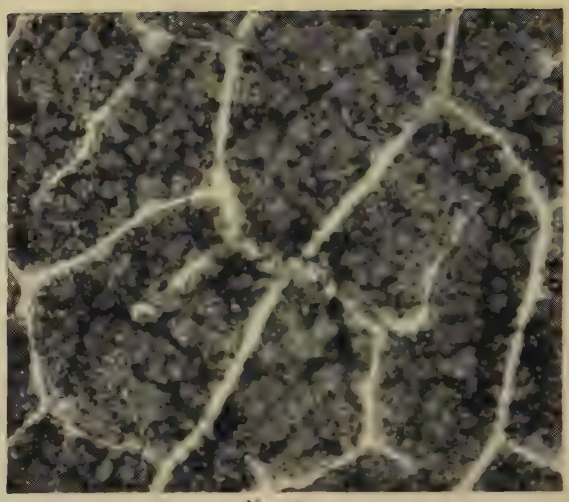
Fig. 1.

A series of six Laxton's Superb apple leaves, cleared in xylol, showing damage by the Fruit Tree Red Spider Mite. No. 1., top left, undamaged; No. 6, bottom right, badly bronzed.

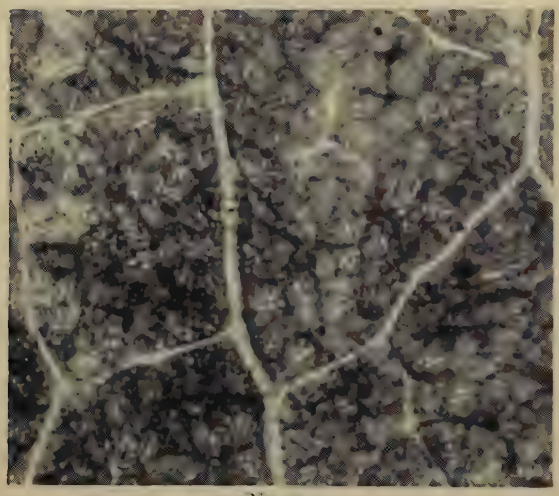
[*face p. 152*



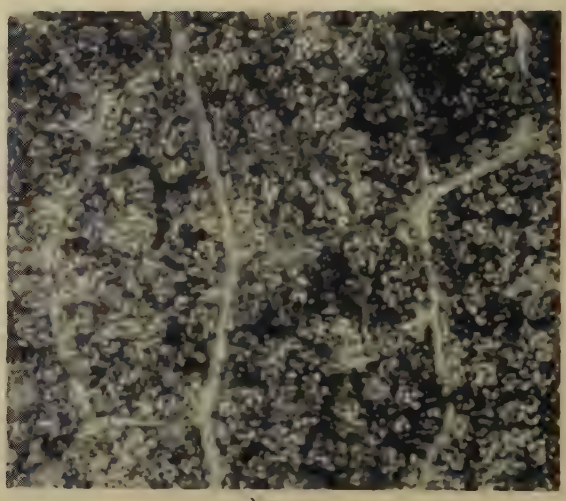
No. 1.



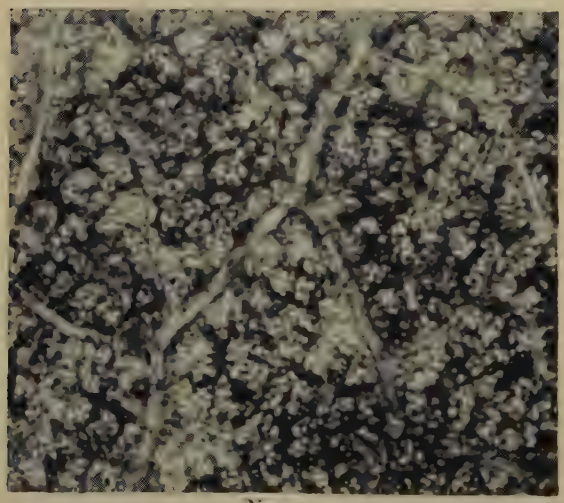
No. 2.



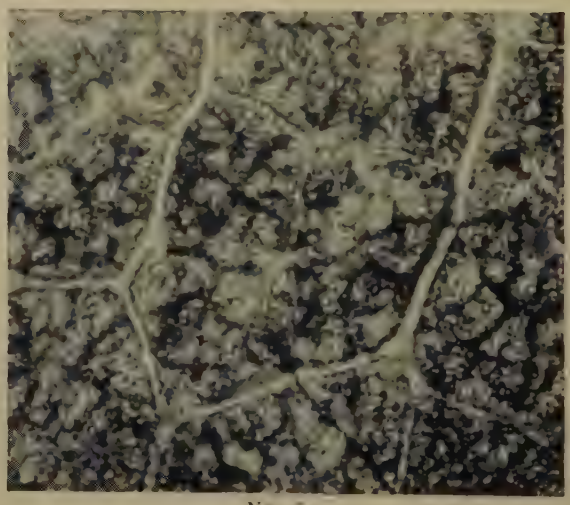
No. 3.



No. 4.



No. 5.



No. 6.

FIG. 2

The lower epidermis of Laxton's Superb apple leaves, showing the feeding punctures of the Fruit Tree Red Spider Mite, *Metatetranychus ulmi* (Koch). × 33.

1. No damage—intensity 1.
2. Slight damage—intensity 2.
3. Medium damage—intensity 3.
4. Badly damaged—intensity 4.
5. Badly damaged—intensity 5.
6. Worst damage—intensity 6.

The extent of the damage done to the leaf can be conveniently demonstrated by removal of the chlorophyll and clearance with xylol. The amber-coloured coagulated material in damaged cells remains, and the depth of colour of the cleared leaf as a whole provides an indication of the proportion affected. Fig. 1 illustrates this in the case of a series of six leaves affected to varying degrees. The damage done to the cells of the lower epidermis can be detected under the Vickers' projection microscope. The series portrayed in Fig. 2 corresponds to that illustrated in Fig. 1.

Relation of damage to winter-egg laying.

During the summer of 1950 winter eggs were found on a block of Laxton's Superb at Porter's Farm, Great Braxted, on the 12th July. This was the earliest record of winter egg-laying which has been made during the six years the investigations have been in progress. The trees had received neither winter petroleum nor summer sprays. By the beginning of July a very heavy infestation had resulted and damage was severe, especially in the centres of the trees. It is possible that the damaged leaves provided insufficient food and that this factor led to the laying of winter eggs. It was therefore decided to record the degree of bronzing reached by a leaf when winter egg-laying commenced.

It was noticed that the degree of infestation by mites on the trees varied throughout the length of the plantation ; the first winter eggs were found on those trees at one end of the orchard which had severely damaged leaves in the middle of the trees and badly damaged leaves throughout. Trees at the other end of the orchard had low populations, showed little damage, and no winter eggs were found. Series of six Laxton's Superb leaves were therefore taken from the orchard, ranging from undamaged through slightly damaged to badly bronzed. On examination after removal of the chlorophyll and clearance with xylol it was found that winter eggs were produced when damage reached a level equivalent to intensity 5 in Figs. 1 and 2.

Varietal resistance to mite attack.

It is well known that varieties of apples vary in their reaction to an attack of Fruit Tree Red Spider Mite. Massee (1929) names five varieties of apple, Lord Derby, Allington Pippin, Worcester Pearmain, Laxton's Superb and Orleans Reinette as liable to severe attack by the Fruit Tree Red Spider Mite. During the study of the habits and life history of the mite the writer has observed severe infestations, sufficient to cause defoliation, on many varieties including Cox's Orange Pippin, Worcester Pearmain, Laxton's Superb, Beauty of Bath, and Early Victoria. In the writer's experience defoliation of Bramley's Seedling is rare in Essex and has only once been observed, although many plantations of this variety have been seen carrying heavy attacks of the mite. Lewis (1945) states that resistance to an attack is an inherited character, and that triploid varieties are less susceptible to attack ; Bramley's Seedling is a triploid variety. Garman (1923) states that thin-leaved varieties of apples are the most susceptible to damage.

During 1949 measurements were made on transverse sections of apple leaves, and it became clear that it was not the thickness of the leaf, but the number of palisade layers which affected the apparent severity of the damage suffered by any particular variety. In 1950 the work was continued, using fresh material, and it is now suggested that the number of layers of palisade mesophyll in the leaf of an apple variety has a direct bearing on the appearance of visible damage (see Table I). The stylets of the mite's mouthparts are 0·14 mm. long when fully expanded, and are thus capable of reaching the upper palisade mesophyll layer in all the varieties of apple listed.

An attack on Early Victoria leaves, which have only one layer of palisade mesophyll, results in an area of damaged cells immediately under the upper epidermis which is easily detectable. In the case of a leaf of Bramley's Seedling, which has two layers of palisade cells or of Monarch, which has three, a similar attack does the same amount of damage to the first layer but the effect will be masked by the one or two layers overlying. A much larger population of mites is therefore required to produce visible bronzing on Bramley's Seedling or on Monarch than on Early Victoria.

Table I shows that Bramley's Seedling has the same number of palisade layers as Laxton's Superb and Worcester Pearmain. The larger area of the Bramley's Seedling leaf means, however, that a greater area of the lower layer of palisade cells is presented to the mite than in the case of the Laxton's Superb or Worcester Pearmain leaf, and an attack which would exhaust the food supply of the lower layer in the Worcester Pearmain or Laxton's Superb and cause bronzing in the top layer would in Bramley's Seedling affect only half or three-quarters of the cells present in the lower palisade layer. This, it is suggested, might account for the lesser damage observed to occur on the latter variety, but the possibility of other, as yet unknown, factors influencing varietal response to mite damage can by no means be ruled out.

TABLE I.

THE THICKNESS AND NUMBER OF PALISADE MESOPHYLL LAYERS OF THE LEAF OF EIGHT VARIETIES OF APPLE.

Variety.	Thickness of leaf. mm.	Number of palisade layers.
Beauty of Bath ..	0·22—0·23	2+
Bramley's Seedling ..	0·20—0·22	2+
Cox's Orange Pippin ..	0·17—0·19	2++
Early Victoria	0·18—0·20	1+
James Grieve	0·22—0·23	2++
Laxton's Superb ..	0·20—0·22	2+
Monarch	0·22—0·23	3
Worcester Pearmain ..	0·17—0·22	2+

The digit represents the number of definite palisade layers. The + represents the number of less definite mesophyll layers between the palisade layers and the spongy mesophyll.

Summary.

An account is given of an investigation of the leaf damage caused by the Fruit Tree Red Spider Mite, *Metatetranychus ulmi* (Koch). Methods for the estimation of the extent of damage are described, and the relationship of the degree of damage exhibited by different varieties to the number of palisade layers present in the leaf is discussed. An instance of winter egg-laying at an unusually early date is related to exhaustion of the food supply in badly affected leaves.

REFERENCES

BLAUVELT, W. E. (1945). The internal morphology of the Common Red Spider Mite (*Tetranychus telarius* Linn.) *Mem. Cornell. agric. Expt. Sta.*, **270**.

GARMAN, P. (1923). The European Red Mite in Connecticut apple orchards. *Bull. Conn. agric. Expt. Sta.*, **418**.

GEIJSKES, D. C. (1938). Waarnemingen over het Fruitspint in verband met zijn bestrijding. *Tijdschr. PlZiekt.*, **44**, 49-80.

L(EWIS), D. (1945). How shall we defeat the Red Spider on fruit trees ? *Answers to Growers, Bull. John Innes*, **1**, 54-7.

MASSEE, A. M. (1929). The Fruit Tree Red Spider. *Rep. E. Malling Res. Sta. for 1928*, 116-22.

TRÄGÅRDH, I. (1915). Bidrag till kännedommen om spinnkvalstren (*Tetranychus* Duf.). *Medd. CentAnst. Försöksv. Jordbr., Stockh.*, **109** (*Ent. Adv.*, **20**).

OBSERVATIONS ON THE DISPERSAL OF THE FRUIT TREE RED SPIDER MITE, *METATETRANYCHUS ULMI* (KOCH)

By GRETL MARLÉ*

Introduction.

During the investigations in Essex on the control of the Fruit Tree Red Spider Mite, it was found that, in plantations which had been sprayed successfully with a late application of winter petroleum, the population of mites at the end of the following summer could rise as high as in previous seasons following upon invasion by mites dispersing from neighbouring orchards (Austin and Massee, 1947). This observation led to a closer study of the factors affecting dispersal and the means by which it is achieved. These may be either active or passive in character.

As the mites overwinter as eggs which are laid on the wood, the pest may be introduced into an orchard on young nursery trees or on graftwood. In both immature and adult stages, the mites may be carried on clothes of workers, on tools, machinery, etc. (Geijskes, 1938).

The main danger to clean orchards, however, lies in the fact that the mites themselves can disperse in large numbers. There are various factors influencing this dispersal, but the main one seems to be lack of food. The leaves of an apple tree must be badly infested and damaged by mites before they will move off to seek new leaves.

Although it was known that dispersal takes place in an orchard by the mites letting themselves down on a fine silken thread (Steer, 1940), it had not been established when and under what conditions this phenomenon occurred. Experiments were therefore carried out under laboratory conditions, using a wind tunnel, and in the field by means of suction traps, grease bands and plates.

Laboratory experiments.

A simple wind tunnel was constructed, that allowed of the speed of the wind passing over the mites being controlled and recorded and accurate measurements of the temperature and humidity of the air being made. It consisted of a box-like apparatus, approximately 8 feet long, with a flared entry at one end and an octagonal diffuser at the other. The widths at the narrowest point of the flared entry and at the furthest point in the diffuser were 12 inches and 15 inches respectively. A 15 inch propeller fan was used, air speed being recorded by means of a very sensitive anemometer inside the tunnel. The wind speed could be varied by means of muslin screens of various thicknesses. Most of the work was done with air speeds of 2½, 5 and 10 m.p.h.

For each experiment, 200 mites were taken from a plantation where dispersal was in progress, and put on to a single damaged leaf on a shoot. The latter was placed in a small plant pot and put inside the tunnel. It was at first thought that the mites would disperse at low wind speeds. It was found, however, that only dead or damaged mites were blown off while the fan was in motion, and that only when it was stopped did the mites descend voluntarily. This they did by spinning a gossamer thread on which they let themselves down.

Only females were observed descending on these fine threads, usually from the highest point on the leaf or from a vein on the under surface, but immature stages of the mite were also seen to spin little threads while being transferred from one leaf to another. It is still uncertain how the males migrate, as they do not appear to spin threads and were not observed dispersing in the wind tunnel. In field dispersal, where they are found in only very small numbers, it may be that they become entangled in the webbing of the females and drift away with them.

It was noted that the females descended sooner after a low wind speed than after a high one. The time taken for mites to descend after exposure to a wind of 10 m.p.h. was significantly greater than that taken after air speeds of 2½ or 5 m.p.h. had been used. Air temperature was always 70° F. or over before dispersal took place and relative humidity was always low, about 50 per cent. The most rapid migration occurred on 8th July, 1949, between 2.55 and 3.25 p.m., after a windspeed of 2½ m.p.h. and at a temperature of 70° F. at the beginning of the experiment, when 28 adult females spun threads and descended in the half hour. In a further experiment on 14th August, 1950, 45 females descended in

* Member of the A.R.C.-Pettar-Ace Red Spider Investigations.

1½ hours after exposure to a wind speed of 5 m.p.h., and a temperature rising from 74·5° F. at the beginning of the experiment to 84·5° F. at the end of it.

These experiments showed that dispersal of the mites takes place only in completely still air, at a high temperature, and that the descent is a voluntary action on the part of the mite, after it has received appropriate external stimuli.

Field experiments.

The experiments carried out in the field confirmed that the act of dispersal on the part of the mite is a voluntary one.

A typical plantation chosen for this work on dispersal was a plot of Laxton's Superb apples at Porter's Farm, Great Braxted, Essex, where the winter egg population was very high. The plot was sprayed with a tar oil winter wash only and no summer spray was used against the Fruit Tree Red Spider Mite. A survey was made of the winter egg density on the plot, and at points of mean density eight greased photographic half plates 4½ inches by 6½ inches were suspended vertically from 4 feet 6 inch poles, facing the prevailing wind. Horizontal plates 6 feet above ground level and horizontal ground plates at 3 inches above ground level gave similar data to the vertical plates and were therefore abandoned, the handling of these plates being less convenient. The oil smeared on to the plates was a light spindle oil (J.D.2). The plates were examined once every 24 hours and the numbers of males, females, immature forms and eggs were counted and recorded.

From these figures it was found that dispersal took place usually in the middle of a generation, i.e. whenever the number of adults collected together on the trees reached a maximum. Thus in the very hot summer of 1947 dispersal peaks were observed in all five generations, the second and third generation peaks being the most marked. The first generation had not built up to sufficiently large numbers for a mass dispersal and by the fourth and fifth generations the numbers were again small following upon the heavy dispersal in the two previous generations. This is clearly shown in Fig. 1.

In 1949 two plantations in Essex were selected for experiments, one of Beauty of Bath apple, and another of Purple Pershore plum. There was a heavy initial population but the mites had all disappeared by the third generation. The trees were quite clean by the end of summer and no fourth and fifth generation dispersal took place (Fig. 2). This early exodus resulted in a low winter egg population and the orchard was comparatively free of mites the following spring.

It will be seen from Table I, which gives the distribution of mite stages caught on the plates as percentages of the total, that by far the greater proportion were adult females.

TABLE I.

MITE STAGES CAUGHT ON THE PLATES DURING JUNE-SEPTEMBER, 1949, AS PERCENTAGES OF TOTAL TRAPPED.

Place.	Eggs.	Immature mites.	Adult males.	Adult females.
Porter's Farm, Great Braxted, Essex	0·86	15·92	4·99	78·21
Great Braxted Hall Farm, Witham, Essex	1·08	10·63	3·99	84·30
Essex Institute of Agriculture, Writtle, Essex	0·0	14·12	5·34	80·53
Shrub Hill Farm, Great Totham, Essex	0·92	7·40	3·70	87·96

Suction traps.

As the numbers of mites caught on the plates depends on the wind speed in the orchard a new type of trap for catching mites was tried which overcomes this objection.

These suction traps were a modification of those used at Rothamsted (Johnson, 1950), and consisted of a 6 inch Vent-Axia fan, on to which was fitted a 3 inch wide flange with an included angle of 30°, with a 23 inch long cone of muslin (52 warp, 53 weft) underneath the fan, ending in a boiling tube. The whole apparatus was supported by a metal tripod whose legs could be adjusted to various heights from the ground.

The boiling tube was secured to a wooden peg in the ground so that the muslin cone was held rigid. A small piece of filter paper, dipped into pyrethrum, and placed into the boiling tube, killed the bigger insects, the mites being mainly found on the muslin. The fans were left on day and night.

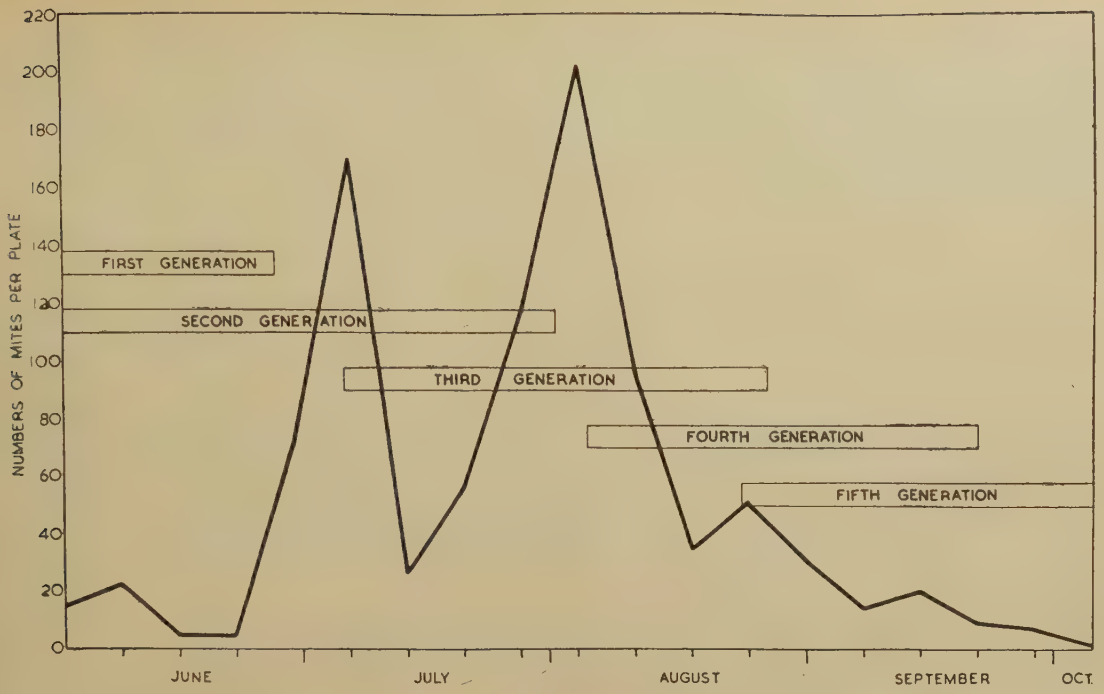


FIG. 1.

Number of Fruit Tree Red Spider Mites recorded on eight greased plates in 1947.

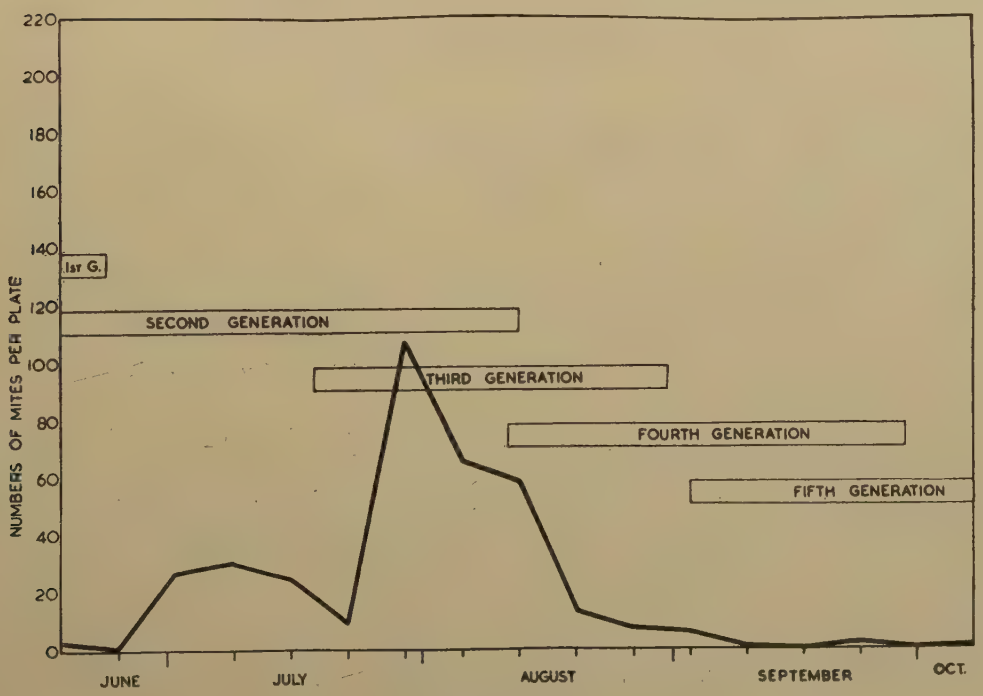


FIG. 2.

Number of Fruit Tree Red Spider Mites recorded on eight greased plates in 1949.

As the suction trap samples air at a constant rate of 5,500 cubic feet per hour, a figure that remains constant up to approximately 12 m.p.h. cross-wind speed, the results obtained from its use proved to be superior to those from the greased plates. Far greater numbers of mites are " caught " in the suction traps than on the plates, e.g. the highest number of mites found in four suction traps in 24 hours, was 874 on 8th July, 1950, and during the same period 55 mites were caught on eight greased plates. Two of these were placed at the same level as the middle of the fan on either side of the suction trap at approximately 3 feet away from it.

The suction traps tend to show the actual number of mites in the air at a given time, and because they sample a continuous stream of air the catch is not so much affected by cross winds as in the case of greased plates, where many of the mites being borne towards the plates may finally be deflected by the layer of static air in front of them.

In the case of a number of insects, the efficiency of the greased plates increases considerably with an increase in wind velocity (Johnson, 1950), but in the case of the Fruit Tree Red Spider Mite the habit of descending voluntarily only in the gentlest of breezes must reduce the value of observations from plates.

Thus it was observed, by making hourly counts, that the largest number of mites was caught during the calmest periods. In 1949, when hourly counts were made between 9 a.m. and 10 p.m., it was found that the greatest number was caught between 8 to 10 p.m., when it was very calm. Similar results were obtained in 1950. Thus on 12th July, 1949, during hourly counts in a plot of plums at Great Braxted the average number of mites in the first eleven hours was 3·9 while the average of the last two hours, 8 to 10 p.m. was 11·5 mites. On 13th July in the same plum plantation the average number of mites caught during the first 10 hours was 7·6 and the average during the last two hours, 7 to 9 p.m., was 16.

Natural dispersal was observed taking place in the plantation on five occasions in 1949 and twice in 1950 ; usually between 7 to 10 p.m., during a calm evening after a warm day, although on two occasions it was seen in the early morning, following upon completely calm nights. Hundreds of mites, all females, were seen hanging from gossamer threads, as many as 20-30 in bunches together, as the threads became entangled. They hung until a gentle breeze broke the threads and then drifted away.

It was noted that hedges of sloe (*Prunus spinosa*) may serve as centres of infestation. In 1948, mites were observed moving from a sloe hedge on to a neighbouring plantation of Cox's Orange Pippin ; the trees nearest the hedge showed mite damage much earlier than the rest of the plantation to which the mites eventually moved. Mites were also found on weeds in very badly infested orchards, e.g. on *Convolvulus arvensis*, *Chenopodium album*, *Senecio vulgaris* and *Trifolium* spp. The mites do lay eggs on these weeds, but it seems unlikely that the weeds are an important source of reinfestation.

Effect of predators on dispersal.

Predators of the Fruit Tree Red Spider Mite sometimes reduce a high population of mites to such an extent that dispersal becomes unnecessary. An instance was observed in a plantation of Laxton's Superb apples in Essex, in 1950, which was heavily infested. The predators, *Stethorus punctillum* (Wei.) and *Blepharidopterus angulatus* (Fall.), reduced the numbers of eggs laid by the second and third generations to such an extent that there was very little dispersal in the third generation and practically none in the fourth and fifth.

Again, in 1947 a very high winter egg population was completely wiped out by *Conwentzia pineticola* End. Such cases suggest that, if there are larger numbers of predators present, the risk of dispersal into a clean orchard from an infested one is considerably reduced, even though the initial infestation of the latter may be high.

Dispersal other than by wind.

In order to discover whether mites move up and down trees by crawling along the trunks, two greased bands 6 to 9 inches apart were put around a number of trees and a hessian screen placed about them to prevent mites from being blown on to the bands. These bands were examined at regular intervals and the mites counted. The numbers were, however, very small. It seems unlikely that mites could return to the trees, once they had fallen to the ground, in large enough numbers to cause damage.

Acknowledgements.

The author wishes to thank Dr. C. G. Johnson, Rothamsted Experimental Station, for his advice on the use of suction traps, and also Dr. P. H. Gregory of Rothamsted and Mr. C. Salter, M.A., of the National Physical Laboratory, for their help in the construction of the low speed wind tunnel.

Summary.

Field and laboratory investigations upon the conditions under which air dispersal of the Fruit Tree Red Spider Mite occurs are reported. The great majority of those migrating are adult females, which disperse at periods of peak population in each generation ; the numbers moving are dependent upon the degree of infestation of the host. Parachute threads are normally formed in still air, following upon relatively calm periods, when temperatures are above 70° F. and relative humidities low.

The use of a wind tunnel, suction air traps and grease plate traps in these experiments is discussed.

References

Austin, M. D. and Massee, A. M. (1947). Investigations on the control of the Fruit Tree Red Spider Mite (*Metatetranychus ulmi* (Koch)) during the dormant season. *J. Pomol.*, **23**, 227-52.

Geijskes, D. C. (1938). Waarnemingen over het fruitspint in verband met zijn bestrijding. *Tijdschr. PlZiekt.*, **44**, 49-80.

Johnson, C. G. (1950). A suction trap for small airborne insects which automatically segregates the catch into successive hourly samples. *Ann. appl. Biol.*, **37**, 80-91.

——— (1950). Comparison of suction trap, sticky trap and tow net for the quantitative sampling of small airborne insects. *Ann. appl. Biol.*, **37**, 268-85.

Steer, W. (1940). Migration of the Red Spider. *Gdnrs' Chron.*, 20th July, 28-9.

PLANT PROTECTIVE CHEMISTRY

TRIALS OF ZINC FLUOROARSENATE AGAINST CODLING MOTH, *CYDIA POMONELLA* L.

By A. H. M. KIRBY

Introduction.

The standard control measure for Codling Moth in this country is to spray with acid lead arsenate, usually at 2 lb. per 100 gallons, during June. With hard water, acid lead arsenate is slightly decomposed to yield a water-soluble arsenic compound, usually considered to be arsenic acid. This may be sufficient to cause partial defoliation of fruit-trees, although the danger arising from the use of lead arsenate is less than that of calcium and some other arsenates. It is usually required to spray apple trees with lead arsenate at the same time as one of the fungicidal sprays is put on ; thus the compatibility of lead arsenate and lime-sulphur is of importance. With dilutions of lime-sulphur down to 2 per cent no great release of soluble arsenic is found in such mixtures, but as dilution is increased beyond this more arsenic passes into solution. As the concentration of lime-sulphur suitable for use on apple trees in June is 1 per cent or less, there is a risk in using a combined spray containing lead arsenate.

Another metallic arsenate, zinc fluoroarsenate, was developed in Sweden during the war years and attained some prominence as a means of controlling phytophagous larvae. When, in 1946, a small supply reached this country, it was suggested that it might be of value on fruit as an alternative to lead arsenate. Of particular interest was the claim that this arsenate released no soluble arsenic when added to weak lime-sulphur solutions. Determinations of soluble arsenic in various dilutions of lime-sulphur, to which either zinc fluoroarsenate or lead arsenate had been added were therefore made. From this investigation it appeared that zinc fluoroarsenate did, in fact, release much less soluble arsenic than was produced from lead arsenate at all dilutions of lime-sulphur tested. Thus there was reason to suppose that mixtures of lime-sulphur and zinc fluoroarsenate might cause less leaf or fruit drop than is usually seen following sprays of lead arsenate plus weak lime-sulphur.

No evidence, however, was available regarding the toxicity of zinc fluoroarsenate toward Codling Moth larvae, and in 1948 a trial was carried out in which the new arsenate was compared with lead arsenate, in the absence of lime-sulphur, on the variety Charles Ross. The results of this trial were favourable in that the new arsenate gave very nearly as good, if not quite as good, control as the standard lead arsenate spray.

Taking up this study in 1949, the present author repeated the 1948 trial, extending it to cover a second variety of apple, Worcester Pearmain, and also carried out a comparison of the phytotoxicity of mixtures of either arsenate with lime-sulphur on two varieties of apple on another plot. The incidence of Codling Moth on Worcester Pearmain trees receiving zinc fluoroarsenate was not significantly less than that on unsprayed control trees, but the incidence on lead arsenate-treated trees was. Thus it appeared that control by lead arsenate was superior to that by zinc fluoroarsenate. There was no significant difference on Worcester Pearmain in regard to leaf fall between unsprayed controls and trees receiving either lead arsenate, or zinc fluoroarsenate, plus 1 per cent lime sulphur. But on Cox's Orange Pippin, there was significantly greater leaf fall with either mixture than from unsprayed controls ; as, however, the leaf fall following zinc fluoroarsenate plus lime-sulphur was not significantly less than that following the mixture containing lead arsenate, there was reason to suppose that damage from the one mixture was as great as that from the other, and that the promise held out by the early laboratory compatibility tests had, in fact, failed to be realized.

In 1950, the two arsenates were again compared for Codling Moth control, this time on Charles Ross only. The phytotoxicity tests were repeated on Cox's Orange Pippin and Worcester Pearmain in May, but as the sprays applied failed to cause leaf fall in either case, a further comparison of mixtures left overnight before application was made in August, however, again with no result. Thus no conclusion regarding the relative phytotoxicity of mixtures of either of the arsenates with lime-sulphur can be drawn on the basis of work in 1950. The control of Codling Moth by lead arsenate was poor this year, but that by zinc fluoroarsenate was certainly no better.

Experimental results.

Details of the laboratory and field trials referred to above are given below.

Laboratory tests.

Mixtures were prepared of either lead arsenate or zinc fluoroarsenate, 0·2 per cent, with various concentrations of lime-sulphur. The mixtures were stirred mechanically for half-an-hour, and then allowed to settle for one hour, the supernatant being subsequently filtered. Thiosulphate present in the filtrate was destroyed by heating 100 ml. with 5 gm. sodium peroxide, dissolved in 50 ml. water, until colourless. The solution was acidified with dilute HCl and evaporated to dryness. The residue was taken up in 50 ml. water plus 3 ml. sulphuric acid, boiled, filtered and the filter-paper washed with 50 ml. hot water. After 1 gm. KI had been added, the solution was evaporated to 40 ml., cooled and diluted to about 200 ml., and 0·005 N thiosulphate run in dropwise, without starch indicator, until iodine colour was removed. After neutralizing with sodium bicarbonate, and adding 4 to 5 gm. excess, the arsenious ions were titrated with 0·01 N iodine, using starch as indicator. The results are summarized in Table I. The arsenic is expressed as As_2O_5.

TABLE I.

PERCENTAGE OF WATER SOLUBLE ARSENIC PRESENT IN MIXTURES OF LIME-SULPHUR WITH LEAD ARSENATE OR ZINC FLUOROARSENATE.

Mixture.		Percentage As_2O_5 in filtrate.
Lime-sulphur + lead arsenate.		
2·0%	0·2%	0·00436
1·0%	do.	0·01860
0·5%	do.	0·04590
0·0%	do.	0·00046
Lime-sulphur + zinc fluoro-arsenate		
2·0%	0·2%	0·00092
1·0%	do.	0·00120
0·5%	do.	0·00230
0·0%	do.	0·00006

While the greater liberation of soluble arsenic with increasing dilution of the lime-sulphur is clearly shown in both cases, it is also obvious that considerably more was released in the lead arsenate mixtures than in the corresponding zinc fluoroarsenate mixtures.

Field trials.

1948. A long narrow plot of 110 mature trees of Charles Ross, planted diagonally, were used. It was thus possible to arrange four replications, each of twelve trees, of two treatments. Controls were provided by leaving the centre twelve trees unsprayed together with the outer rows of the outermost plots. Bramley's Seedling was present in the plot, one tree in nine, but these were not used for recording, which was carried out on the total crop from the centre two trees of each plot.

Codling Moth eggs were first noted on 10th June, but were found up to the middle of August. Spraying was carried out on 23rd June in fine, warm weather with a light S.W. breeze. No serious drift occurred and the double guard-rows were fully adequate. Both arsenates were used at 0·2 per cent, no wetter was added and it was noted that wetting was not good.

It is sometimes said that Charles Ross is a variety susceptible to leaf damage due to post blossom arsenical spraying, and records of leaf fall and fruit drop were taken. There was, however, a general slight leaf fall on Charles Ross and on nearby Miller's Seedling, beginning before spraying was carried out, and there was no evidence that either arsenate accentuated this or affected fruit drop.

The results for the trial are summarized in Table II.

TABLE II.

DEGREE OF INFESTATION OF FRUITS WITH CODLING MOTH ON TREES OF CHARLES ROSS SPRAYED WITH LEAD ARSENATE OR ZINC FLUOROARSENATE IN 1948.

Treatment.	Total fruits from recorded trees.	Percentage fruits infested.
Lead arsenate 0·2%	1,803	1·9
Zinc fluoroarsenate 0·2%	1,011	2·3
Unsprayed	770	17·0

The percentage infestation does not differ significantly for the plots receiving the two arsenates. As the control plots were not randomized, it is not possible to make a strict comparison of the incidences on treated and untreated plots, but it seems that a considerable incidence would have appeared on the whole area but for the treatments, which did not differ in effectiveness.

1949. This trial incorporated the Ross trees used in the previous year and also an adjacent strip containing Worcester Pearmain. By using rows 1, 4 and 7 as guard rows, other varieties were avoided, and two replicates of four trees each were obtained for Ross and for Worcester. Four treatments were with new materials and will not be considered here. The other two treatments were as in 1948, and unsprayed controls were also randomized throughout both blocks. Records were taken on two trees in each replicate plot.

Sprays were applied on 21st June in sunny weather with a light N.E. breeze; 0·01 per cent Aerosol OT was added to both sprays and a good cover was obtained. Both picked and dropped fruit were recorded and the percentages infested are set out in Table III.

TABLE III.

DEGREE OF INFESTATION OF FRUITS BY CODLING MOTH ON TREES OF WORCESTER PEARMAIN AND CHARLES ROSS SPRAYED WITH LEAD ARSENATE OR ZINC FLUOROARSENATE IN 1949.

Treatment.	Percentage fruits infested.	
	Charles Ross.	Worcester Pearmain.
Lead arsenate 0·2%	17·8	3·0
Zinc fluoroarsenate 0·2%	29·3	9·0
Unsprayed	41·5	21·0

It will be noted that the incidence on the unsprayed Charles Ross was much higher than in 1948, but that control even with lead arsenate was much poorer. Control on Worcester Pearmain was relatively better with both arsenates. However, on Charles Ross, lead arsenate was more effective than zinc fluoroarsenate. The latter did not, in fact, differ significantly from the control. In the case of Worcester Pearmain, none of the treatments differed significantly.

The phytotoxic effect of mixtures of lead arsenate or zinc fluoroarsenate, 0·2 per cent, with 1 per cent lime-sulphur was examined by spraying such mixtures on two varieties, Worcester Pearmain on M.IX and Cox's Orange Pippin on M.XII, on 17th June in calm, cloudy weather. Three replications were possible on Worcester Pearmain (whole trees), and six on Cox's Orange Pippin (single-branch treatments). Damage to leaves was recorded on 30th June, employing six categories. The mean values observed are shown in Table IV.

TABLE IV.

PHYTOTOXIC EFFECT (1949): MEAN UNITS OF DAMAGE.

Treatment.	Worcester Pearmain.	Cox's Orange Pippin.
Lead arsenate + lime-sulphur ..	0·6	2·9
Zinc fluoroarsenate + lime-sulphur	0·2	2·6
Control, unsprayed	0·2	1·0

While damage due to the mixture containing lead might have been slightly greater than that due to the zinc mixture on Worcester Pearmain, both mixtures caused considerable leaf damage on Cox's Orange Pippin and there was no significant difference between them.

1950. This trial was a repetition of that carried out in 1948, using the same Charles Ross trees. Sprays were applied on 22nd June, but 0·01 per cent Aerosol OT was incorporated in both. The weather was fine, with sunny periods and a S.S.W. breeze. Dropped and picked crops were recorded and the results are set out in Table V.

TABLE V.

INFESTATION OF FRUITS BY CODLING MOTH ON TREES OF CHARLES ROSS SPRAYED WITH LEAD ARSENATE OR ZINC FLUOROARSENATE IN 1950.

Treatment.	Percentage fruits infested.
Lead arsenate 0·2%	26·3
Zinc fluoroarsenate 0·2%	28·0
Unsprayed	40·9

There was no significant difference between the degrees of infestation of the two series of treated blocks. Statistical comparison with the unrandomized control plots cannot be made, but there was clearly a considerable infestation over the plot, which was not adequately controlled by either treatment.

A further comparison of the phytotoxicity of mixtures of either arsenate plus lime-sulphur was made on Worcester Pearmain on M.IX and Cox's Orange Pippin on M.XII. Mixtures of the same composition as in 1949 were sprayed on 24th May. No significant damage was seen when records were taken on 6th June. Later, it was decided to repeat these treatments, and, to facilitate liberation of soluble arsenic, the mixtures were allowed to stand at room temperature overnight. They were then resuspended, transferred to the spraying machine and put on the same trees on 23rd August. Records were taken on 18th September, but no damage could be found in either case.

Discussion.

It is difficult to avoid the conclusion that zinc fluoroarsenate offers no advantage over lead arsenate as an insecticide for control of Codling Moth.

It does, of course, remove any health hazard due to lead, but arsenic remains and fluorine is brought in. Thus the residue problem remains, especially in the case of early varieties. The cost is greater than that of lead arsenate and, as the proportion of arsenic in the two materials is almost the same, zinc fluoroarsenate would have to be more efficient than lead arsenate to be as economic. Our results indicate that it is no better than, if as good as, the older spray material. If the fact that, in the laboratory, less soluble arsenic is released when zinc fluoroarsenate is mixed with weak lime-sulphur than is the case when lead arsenate is so mixed was reflected in less phytotoxicity in the field, then the zinc compound would have much to recommend it. The 1949 results recorded here indicate that just as much damage can be expected from mixtures of either arsenate with weak lime-sulphur ; unfortunately the 1950 results give no guidance on this point.

It is of interest to note that in Queensland, Caldwell (1947) compared zinc fluoroarsenate with lead arsenate, in eight cover sprays, combined in each case with white oil which is itself safe (May and Fisher-Webster, 1948) in that area. This worker found that the former gave the same degree of control of Codling Moth as did the latter, but that foliage injury was just as severe.

Acknowledgements.

Acknowledgement is made of the results of earlier work by Dr. H. Shaw and Dr. P. Satyanarayana in 1946, and of Dr. J. K. Eaton and Mr. R. G. Davies in 1948, described in the Introduction. The author is indebted to Miss M. Bennett for much assistance with the field trials.

Summary.

1. Laboratory tests indicated that zinc fluoroarsenate yields less soluble arsenic when mixed with weak lime-sulphur than does the equivalent amount of lead arsenate.

2. Phytotoxicity tests with such mixtures on Worcester Pearmain and Cox's Orange Pippin indicated that just as much leaf-damage may be caused by zinc fluoroarsenate as by lead arsenate, at least on Cox's Orange Pippin.

3. Direct comparison of Codling Moth control by the two arsenates showed no indication of a difference in effectiveness.

4. As zinc fluoroarsenate is a little more expensive than lead arsenate, and on most other grounds appears to offer no advantage over lead arsenate, there seems no reason at present to recommend its use for Codling Moth control on apples.

References

Caldwell, N. E. H. (1947). Developments in Codling Moth control. *Queensland Dept. of Agric. and Stock, Advisory Leaflet* **123.**

May, A. W. S., and Fisher-Webster, K. G. (1948). Codling Moth control experiments, 1947-8. *Queensland Dept. Agric. and Stock, Advisory Leaflet* **140.**

LABORATORY EXPERIMENTS ON THE TOXICITY OF POTENTIAL ACARICIDES

By A. H. M. KIRBY and K. S. McKINLAY

The results of laboratory tests of many compounds for toxicity to the winter or summer eggs and the adult females of the Fruit Tree Red Spider Mite, *Metatetranychus ulmi* (Koch), in 1947 and 1948 have been reported by Eaton and Davies (1950*a*, *b*). Although a number of promising materials were discovered or confirmed, and some of these have been used in field trials, the need for further search was apparent, and laboratory trials were continued in 1949 and 1950.

The choice of compound was determined by indications from the previous work referred to above and from field trials based mainly upon that work, and from work published elsewhere. The compounds tested are grouped according to their chemical nature, or other interest, in the tabulation of results below. A special trial was also made to ascertain whether certain materials were ovicidal when applied to the opposite side of the leaf to that on which eggs were present.

Methods.

The methods of testing material against the summer forms of this pest in 1949 were those described by Eaton and Davies (1950*a*). As these authors admit, the ovicide method is tedious and an attempt to shorten it was made in 1950. Instead of using whole leaves for the ovicide tests, circles were cut out with a cork-borer after active forms had been removed by suction and the leaf had been dipped in the test fluid ; the circles were then stored on moist filter paper in small petri dishes. These circles were just large enough to fill the field of the binocular dissecting microscope, and were selected to provide about 30-40 eggs each, 8 to 10 circles per test giving a total of about 300 eggs. The time required for removing active forms, dipping, cutting out circles and storing was not much less than for whole leaves, but the task of counting unhatched eggs was greatly simplified. Very few tests with adult females were made in 1950 as the method used by Eaton and Davies (1950*a*, *b*) and by us in 1949 is not very satisfactory.

Formulation of our materials was made, wherever possible, in 2 per cent acetone, 0·05 per cent *cyclo*-hexylamine dodecyl sulphate, MB320, and 0·02 per cent di-octyl sodium sulphosuccinate, Aerosol OT 100. This formulation will be referred to as " standard " throughout this paper and deviations from it will be stated in detail.

Results—Organophosphorus compounds.

Eaton and Davies (1950*a*) reported tests with eleven organophosphorus compounds including parathion and its oxygen analogue, para-oxon. The sample of parathion available to them was only 75 per cent pure, but samples of a purity approaching 100 per cent became available to us in 1949 and 1950, the 1950 sample being regarded by the manufacturers as being over 99 per cent pure. Pure samples of two homologues of parathion, the O,O-dimethyl and the O,O-di-isopropyl, were provided from the same source ; a pure sample of para-oxon and an analogue of this compound, O,O-diethyl-O-*p*-chlor-*m*-methylphenyl phosphate, were obtained from another source. The standard formulation was used for parathion, para-oxon and the analogue tested in 1949, but in 1950 two other formulations, A and B, were employed :

A, 2 per cent diacetone alcohol and 0·1 per cent Lissapol N.

B, 2 per cent acetone and 0·1 per cent Lissapol NXA (an anhydrous form of Lissapol N).

The results of these tests are set out in Table I.

Parathion and para-oxon also gave 100 per cent kill of adult females at both concentrations in 1949 ; the other compounds were not tested against adult females.

Para-oxon proved a superior ovicide in both years to parathion, but it must be remembered that even the lower concentration employed is higher than desirable for field use. The higher mortalities in 1950 are more likely to be due to greater susceptibility of 1950 eggs than to greater purity of the chemical, but the change in formulation may also have played a part.

The dimethyl homologue of parathion proved considerably inferior to parathion, but the di-*iso*-propyl homologue was of intermediate toxicity ; Metcalf and March (1949) found the order of toxicities

TABLE I.

PERCENTAGE MORTALITY (c = 0) OF SUMMER EGGS OF THE FRUIT TREE RED SPIDER MITE DIPPED IN FORMULATIONS OF VARIOUS ORGANOPHOSPHORUS COMPOUNDS.

Compound.	1949.		1950.			
			Formulation A.		Formulation B.	
	0·1%	0·025%	0·1%	0·025%	0·1%	0·025%
Parathion	59·5	28·5	86·4	44·5	65·1	55·5
Dimethyl homologue of parathion	—	—	14·8	14·9	19·9	2·3
Di-*iso*-propyl homologue of parathion	—	—	62·2	14·6	52·5	3·8
Para-oxon	82	58·7	92·4	76·2	97·1	52·7
O,O-diethyl-O-*p*-chlor-*m*-methylphenyl phosphate ..	0·0	0·0	—	—	—	—

toward worker bees and houseflies to be parathion > dimethyl homologue > di-*iso*-propyl homologue. The complete absence of activity, up to 0·1 per cent, of the *p*-chlor-*m*-methyl analogue of para-oxon is perhaps not surprising in view of the results of these workers who found the toxicity of para-oxon towards houseflies to be about 300 times that of the *p*-chlor analogue.

One other organophosphorus compound has received preliminary testing, namely, E838, which is O,O-diethyl-O-4-methyl-7-hydroxycoumaryl thionphosphate, an analogue of parathion. This material was only available as a dust formulation. Acetone extraction of this dust removed 1·8 per cent of it, and this extract was made up in the standard formulation to give a final concentration of 0·1 per cent E838. The percentage mortality of eggs dipped in this suspension was 89·2, and it is hoped to make further studies of pure material in 1951.

Chlorinated hydrocarbons.

Five recently developed compounds of this type were tested : γ-benzene hexachloride, 92 per cent pure ; chlordane, 90 per cent active ingredient(s) ; toxaphene, 100 per cent active ingredient(s) ; aldrin, 95 per cent active ingredient ; dieldrin, 85 per cent active ingredient.

The standard formulation was used for all these compounds and the results are set out in Table II.

Toxaphene was also tested against adult females at the same concentrations and the respective mortalities were 50 and 1·2 per cent. It is thus the first chlorinated hydrocarbon to show definite action against this pest, and it obviously has advantages over DDT and BHC in this respect.

The ovicidal activity of aldrin and dieldrin is very encouraging ; it will be interesting to examine their action against adult mites. However, there is no likelihood that these materials will be of any use as direct toxicants to this pest.

TABLE II.

PERCENTAGE MORTALITY (c = 0) OF SUMMER EGGS OF THE FRUIT TREE RED SPIDER MITE DIPPED IN A FORMULATION OF FIVE CHLORINATED HYDROCARBONS.

Compound.	1949.		1950.	
	0·1%	0·025%	0·1%	0·025%
γ-BHC	0·0	0·0	—	—
Chlordane	0·0	0·0	—	—
Toxaphene	4·0	0·0	—	—
Aldrin	—	—	69·5	56·6
Dieldrin	—	—	47·4	66·4

***Cyclo*-hexylamines.**

N,N-Amyl benzyl *cyclo*-hexylamine was shown by Compton and Kearns (1937) to give good control, without phytotoxicity on sensitive plants, of the Greenhouse Red Spider ; this material was marketed shortly afterwards as Santobane A. Two other *cyclo*-hexylamines, the N-amyl and the N,N-amyl

benzoyl, were also shown by Kearns and Flint (1937) to be acaricidal. Samples of these three compounds, provided by the manufacturers, were tested in 1949 against eggs and adult females, using the standard formulation. Results are given in Table III.

TABLE III.

PERCENTAGE MORTALITY (C = 0) OF SUMMER EGGS AND ADULT FEMALES OF THE FRUIT TREE RED SPIDER MITE DIPPED IN A FORMULATION OF THREE SUBSTITUTED *cyclo*-HEXYLAMINES.

Compound.	Summer eggs.		Adult females.	
	0·1%	0·025%	0·1%	0·025%
N-amyl	54·2	31·0	19·2	15·2
N,N-Amyl benzoyl ..	67·6	33·0	70·0	10·4
N,N-Amyl benzyl	71·5	75·6	100·0	52·2

Of these compounds, N,N-amyl benzyl *cyclo*-hexylamine is obviously very effective at 0·1 per cent.

Benzhydrols.

Diphenyl carbinol (benzhydrol) was tested by Eaton and Davies (1950*b*) and found to be slightly toxic to summer eggs and to cause a mortality of about 40 per cent among adult females, at 0·1 per cent. On the other hand, bis(*p*-chlorphenyl) methylcarbinol (DMC), at the same concentration, caused 100 per cent mortality among adult females and killed nearly as large a proportion of eggs. Metcalf (1948) has shown bis(*p*-chlorphenyl) carbinol to be less than one-tenth as toxic as DMC toward the Citrus Red Mite, but neither this compound nor the bis(*o*-chlorphenyl) isomer appear to have been tested against the Fruit Tree Red Spider Mite. Tests were made in 1950 with these four compounds against summer eggs only.

A commercial sample of benzhydrol was recrystallized from petroleum ether, b.p. 60-80° C.; m.p. 68° C. Bis(*o*-chlorphenyl) carbinol, m.p. 87·5-88° C., was kindly supplied by Dr. Hubert Martin. Bis(*p*-chlorphenyl) carbinol was synthesized via the corresponding phenone, and after crystallization from petroleum ether, b.p. 60-80° C., containing a little benzene, the white product melted at 94° C. DMC was also recrystallized from petroleum ether, b.p. 60-80° C., and then melted at 67-68° C.; Grummitt (1950) gives m.p. 69·5 to 70° C. for this compound. The standard formulation was used, and results are given in Table IV.

TABLE IV.

PERCENTAGE MORTALITIES (C = 0) OF SUMMER EGGS OF THE FRUIT TREE RED SPIDER MITE DIPPED IN A FORMULATION OF SEVERAL BENZHYDROLS.

Compound.	0·1%	0·025%
Benzhydrol	53·6	19·7
Bis(*o*-chlorphenyl) carbinol	42·4	40·7
Bis(*p*-chlorphenyl) carbinol	60·0	16·7
Bis(*p*-chlorphenyl) methyl-carbinol (DMC)	78·7	68·9

The toxicity of benzhydrol was much greater than that found by Eaton and Davies (1950*b*), but that of DMC decidedly less. The value of the methyl group in DMC seems, however, to be definite as bis(*p*-chlorphenyl) carbinol is a good deal less toxic, but chlorination in the ortho positions also seems to give a fairly active ovicide. DMC is still the most active benzhydrol so far examined.

Benzyl benzoates.

Eaton and Davies (1950*b*) reported benzyl benzoate to have little activity against summer eggs, but to cause between 80 and 90 per cent mortality among adult females, at 0·1 per cent. On the basis of this result, this compound was given a preliminary field trial in 1948 and, having been found non-phytotoxic, was given a larger scale trial in 1949. It was no more ovicidal in the field than it had

appeared in the laboratory, but it proved of special interest in that predators of the Fruit Tree Red Spider Mite were much more active on trees sprayed with it than on trees treated with other acaricides. It seemed worth while, therefore, to examine the activity of some modifications of this compound in the hope of increasing acaricidal potency without impairing the low toxicity to predators. Kenaga (1949) reported that *p*-chlorination of phenyl benzoates gave the following order of toxicities toward the Two-Spotted Spider Mite, *Tetranychus bimaculatus* Harvey : phenyl benzoate = phenyl *p*-chlorbenzoate < *p*-chlorphenyl benzoate < *p*-chlorphenyl *p*-chlorbenzoate, the last being a great improvement as an ovicide. The corresponding four benzyl benzoates were therefore prepared and tested in 1950 against both summer eggs and adult females of the Fruit Tree Red Spider Mite. Benzyl benzoate, a commercial sample, was purified by distillation at 0·25-0·3 mm., the fraction distilling between 110-115° C. being collected. The three chlorinated compounds were prepared by reacting the appropriate alcohols and acid chlorides in pyridine. The melting-points were as follows : *p*-chlorbenzyl benzoate, 122° C. ; benzyl *p*-chlorbenzoate, 34° C. ; *p*-chlorbenzyl *p*-chlorbenzoate, 81° C.

Benzyl benzoate and the two mono-chlor esters were formulated by the standard method, but it was found necessary to use 5 per cent acetone for *p*-chlorbenzyl *p*-chlorbenzoate. Separate formulation controls were included, but the increase in acetone content made no difference to the mortality. Results are set out in Table V.

Table V.

Percentage mortalities (c = 0) of summer eggs and adult females of the Fruit Tree Red Spider Mite dipped in formulations of four benzyl benzoates.

Compound.	Summer eggs.		Adult females.	
	0·1%	0·025%	0·1%	0·025%
Benzyl benzoate	0·0	21·9	73·1	65·5
p-Chlorbenzyl benzoate ..	41·2	0·7	82·9	72·6
Benzyl-*p*-chlorbenzoate ..	22·7	0·0	96·5	94·3
p-Chlorbenzyl *p*-chlorbenzoate	0·0	0·0	53·1	28·1

Improved activity against both eggs and adults was achieved by introducing a chlorine atom at either end of the molecule, but chlorination at both ends reduced the toxicity towards the adult and left the ovicidal activity negligible. Unfortunately, chlorination at one end appears to favour high acaricidal action, whereas the greater ovicidal action belongs to the compound with a chlorine atom at the other end. Both these compounds deserve field testing as the effects on predators cannot be determined in the laboratory.

Phenyl benzenesulphonates.

Kenaga and Hummer (1949) reported exceptional toxicity to the eggs of the Two-Spotted Mite for *p*-chlorphenyl *p*-chlorbenzenesulphonate. Phenyl benzenesulphonate and the two para-chlorinated esters were of low toxicity. None of these compounds showed high acaricidal activity. *p*-Chlorphenyl *p*-chlorbenzenesulphonate is now on the market, in the U.S.A. and Canada, under the trade reference K6451 and has special value on account of its long persistence (Armstrong, 1950 ; Chapman and Lienk, 1950 ; Dean, 1950). Dean (1950) has also reported good field control of European Red Mite, *Paratetranychus pilosus*, C & F., *Metatetranychus ulmi* (Koch), with this material.

It was decided to compare K6451 with the other phenyl benzenesulphonates referred to above against summer eggs of the Fruit Tree Red Spider Mite. K6451 was recrystallized once from methanol, m.p. 85° C. Phenyl benzenesulphonate and the two monochlorinated esters were prepared by reacting the appropriate phenols and acid chlorides in pyridine. Phenyl *p*-chlorbenzenesulphonate crystallized from the reaction mixture and was finally crystallized from methanol ; m.p. 93° C. Phenyl benzenesulphonate and the *p*-chlorphenyl ester failed to crystallize and were distilled at 3 mm. Phenyl benzenesulphonate was redistilled at 0·4 mm. and crystallized in a freezing-mixture ; m.p. 36° C. *p*-Chlorphenyl benzenesulphonate, after one distillation, crystallized on standing and was recrystallized from methanol ; m.p. 64° C. These materials formulated readily, but only 0·01 per cent Aerosol OT was used. Four concentrations of each material were employed, and the results are given in Table VI.

TABLE VI.

PERCENTAGE MORTALITIES (c = 0) OF SUMMER EGGS OF THE FRUIT TREE RED SPIDER MITE DIPPED IN A FORMULATION OF FOUR PHENYL BENZENESULPHONATES.

Compound.	0·1%	0·05%	0·025%	0·0125%
Phenyl benzenesulphonate	39·9	10·2	72·1	5·6
Phenyl *p*-chlorbenzenesulphonate ..	86·1	43·6	51·2	35·4
p-Chlorphenyl benzenesulphonate ..	94·7	88·6	86·8	68·7
p-Chlorphenyl *p*-chlorbenzenesulphonate (K6451)	92·4	71·6	91·9	30·9

Phenyl benzenesulphonate has only moderate toxicity even at 0·1 per cent, but the other three compounds all show considerable ovicidal activity at this concentration, phenyl *p*-chlorbenzenesulphonate being the least effective. Contrary to the findings of Kenaga and Hummer (1949) for the Two-Spotted mite, *p*-chlorphenyl benzenesulphonate is at least as toxic to the summer eggs of the Fruit Tree Red Spider Mite as is the *p*,*p*'-dichlor-compound, K6451, and its toxicity seems greater at lower dilutions than that of K6451. Only field tests will show which of these two compounds is preferable for mite control, but experience in America and Canada is very encouraging as far as K6451 is concerned.

Fungicides.

The possibility of combating scab with a fungicide which also had acaricidal properties is always attractive. It has been claimed that Arathane, which contains dinitro capryl phenylcrotonate, is active against Apple Scab and European Red Mite, and the recent report of Lathrop and Hilborn (1950) shows that both disease and pest were successfully controlled by Arathane in 1949 in a Maine, U.S.A., orchard. A laboratory test was therefore made in 1949 of Arathane, which is a wettable powder containing 25 per cent of the active ingredient, against both eggs and adult females, using no supplementary formulation. Tests were also made that year with two alkyl glyoxalidine fungicides, 341C and 341SC, again without supplementary formulation. In 1950, tests were made with SR406, which is N(trichlormethylthio)-tetrahydrophthalimide, formulating with 5 per cent acetone, 0·05 per cent MB 320 and 0·02 per cent Aerosol OT. Results for the three types of fungicide are given in Table VII, concentrations referring in all cases to active ingredient.

TABLE VII.

PERCENTAGE MORTALITIES (c = 0) OF SUMMER EGGS AND ADULT FEMALES OF THE FRUIT TREE RED SPIDER MITE DIPPED IN FORMULATIONS OF VARIOUS FUNGICIDES.

Fungicide.	Summer eggs.		Adult females.	
	0·1%	0·025%	0·1%	0·025%
Arathane (WP25) ..	79·2	68·9	85·4	100·0
341C	9·6	0·0	41·5	0·0
341SC	9·5	16·3	23·5	30·5
SR406 (1950 tests) ..	63·0	53·5	—	—

It will be seen that Arathane is promising both as an acaricide and as a summer ovicide. The alkyl glyoxalidines, however, show no promise for the direct control of the Fruit Tree Red Spider mite. SR406, on the other hand, has considerable ovicidal action and could well act as a supplementary spray material against this pest when used primarily as a fungicide against scab.

Unclassified materials.

Related to benzyl benzoate are the cresyl benzoates which have been shown to be active against mites parasitic on mammals. Two of these benzoates, the *m*-cresyl and the *p*-cresyl, were synthesized and tested in 1949. By contrast, the benzoyl derivative of a base, aniline, was also tested, and further tests of two promising compounds examined by Eaton and Davies (1950*b*), azobenzene and azoxybenzene, were also made in 1949. All the above were tested against eggs and adult females, but 1950 tests on two formulations of DMC, on DPS and an analogue, and on the active constituent of the

American acaricide, Aramite, were confined to summer eggs. Formulation was standard for all materials except the manufacturers' formulation of DMC which was Dimite, containing 25 per cent active ingredient. Results are given in Table VIII.

TABLE VIII.

PERCENTAGE MORTALITIES (c = 0) OF SUMMER EGGS AND ADULT FEMALES OF THE FRUIT TREE RED SPIDER MITE DIPPED IN FORMULATIONS OF VARIOUS CHEMICALS.

Compound.	Summer eggs.			Adult females.	
	0·1%	0·025%	0·01%	0·1%	0·025%
m-Cresyl benzoate	16·6	8·7	—	38·1	—
p- ,, ,, ...	2·3	0·0	—	72·5	3·2
Benzoyl anilide	0·0	0·0	—	1·0	0·0
Azobenzene	—	—	78·7	100·0	30·0
Azoxybenzene	69·3	55·9	—	83·5	33·9
Bis(*p*-chlorphenyl) methyl carbinol (DMC) ..	88·5	86·2	—	—	—
Dimite (DMC)	87·2	91·7	—	—	—
Diphenyl sulphone (DPS)	91·0	—	—	—	—
4-Chlorphenyl-chlormethyl sulphone	87·7	—	—	—	—
β-Chlorethyl-β-(*p-tert.*butyl-phenoxy)α-methyl ethyl sulphite	65·0	54·1*	10·9	—	—

* Concentration : 0·033 per cent.

The cresyl benzoates offer no advantage over benzyl benzoate, and benzoyl anilide is inactive toward eggs or mites. Azobenzene was again shown to be highly active, but is, like azoxybenzene, too phytotoxic for field use. Both formulations of DMC proved equally effective. The analogue of diphenyl sulphone, which has only one phenyl group and is known as Lauseto-neu, was nearly as effective as diphenyl sulphone itself. The active constituent of Aramite, while showing considerable toxicity, is not likely to prove of value for field control.

Penetration through leaves.

Blauvelt and Hathaway (1950) drew attention to the excellent control of Greenhouse Red Spider by aerosols containing K6451, although the deposit was mainly on the upper surface of leaves. As the fumigant effect of this toxicant was shown to be of little importance, it appeared that the effect on eggs laid on the lower surface of leaves was achieved by permeation of the toxicant through the leaves and then into the eggs. Such permeation of leaves is already known for parathion, resulting in the death of aphids feeding on the lower surface of leaves treated with parathion on the upper surface. It was considered of interest to examine the effect on summer eggs of the Fruit Tree Red Spider Mite of this toxicant K6451, and its promising analogue, *p*-chlorphenyl benzenesulphonate, as well as of parathion, para-oxon, azobenzene, diphenyl sulphone, DMC and rotenone, all applied to the upper surface only of egg-laden leaves. These materials were therefore formulated by our standard method, using concentrations known to be ovicidal except in the case of rotenone which is only acaricidal. The formulated toxicants were then applied by means of a camel-hair brush, to the upper surface of leaves bearing an adequate number of eggs on the lower surface. The effect in each case was determined by the old technique, using whole leaves throughout. The results are summarized in Table IX.

As could be expected, rotenone, even at 2·5 times the concentration used in the field to kill adult mites, failed to have any ovicidal action. However, DMC at four times the strength required for effective direct ovicidal action, and DPS at twice that strength, failed to kill eggs separated from their deposits by a leaf. But azobenzene, at 0·1 per cent, showed a definite toxic action through the leaf, and this effect was marked in the case of the other four compounds tested. The organophosphorus compounds were employed at five times the field strength usual for parathion and, no doubt, the effect at 0·01 per cent would be much less, if any. But the benzenesulphonates were used at the present recommended field-strength and the effect described may be expected to hold in the field as well as in the glasshouse. It should be noted that *p*-chlorphenyl benzenesulphonate was twice as effective as K6451, and it can be suggested that aerosols containing the former would be even more effective in the greenhouse than are aerosols containing the latter.

TABLE IX.

PERCENTAGE MORTALITIES (C = 0) OF SUMMER EGGS OF THE FRUIT TREE RED SPIDER MITE DUE TO PERMEATION OF LEAVES BY VARIOUS TOXICANTS.

Compound.	Percentage concentration.	Percentage mortality.
p-Chlorphenyl *p*-chlorbenzenesulphonate (K6451) ..	0·1	32·0
p-Chlorphenyl benzenesulphonate	0·1	68·3
Parathion	0·05	33·3
Para-oxon	0·05	53·8
Azobenzene	0·1	17·2
Bis(*p*-chlorphenyl) methyl carbinol (DMC)	0·2	0·0
Diphenyl sulphone (DPS)	0·2	1·2
Rotenone	0·01	0·0

Discussion.

The tests described range over a considerable number of compound types and topics, but it is worth while trying to draw a few general conclusions from them and from work published previously from here and elsewhere.

The order of activities against the Two-Spotted Mite for phenyl benzoates is given by Kenaga (1949) as : *p*-chlorphenyl benzoate > *p*-chlorphenyl *p*-chlorbenzoate > phenyl *p*-chlorbenzoate = phenyl benzoate, for adult mites, and *p*-chlorphenyl *p*-chlorbenzoate > *p*-chlorphenyl benzoate > phenyl *p*-chlorbenzoate = phenyl benzoate, for eggs. These orders are quite different from those obtained by Eaton and Davies (1950*b*) for azobenzene and diphenyl sulphone, where, in symmetrical molecules, *p*-monochlorination enhanced and *p*,*p*′-dichlorination destroyed activity. Our results with benzyl benzoates are also contrary to Kenaga's findings ; monochlorination at either end of the molecule enhances activity, but chlorination at both ends decreases it, both for eggs and adult mites. Metcalf (1948) drew attention to specificity in acaricides as exemplified by differences in orders of activities against the Two-Spotted Mite and the Citrus Red Mite, and it seems likely that the work carried out here on the Fruit Tree Red Spider Mite is a further illustration of this phenomenon. It seems established that every mite requires separate treatment with regard to acaricide or ovicide testing ; otherwise the best economic toxicants may be missed.

Our observations regarding the phenyl benzenesulphonates are even more striking in this connection. Kenaga and Hummer (1949) report little or no increase in toxicity, toward either eggs or adults of the Two-Spotted Mite, when a chlorine atom is introduced at either end of the phenyl benzenesulphonate molecule ; but chlorination at both ends, while giving a compound still virtually non-toxic toward adults, caused a very marked increase in ovicidal action. With the Fruit Tree Red Spider Mite, ovicidal activity was found in all four compounds and chlorination at either, or both, ends, increased it ; but the order of activities appears to be : *p*-chlorphenyl benzenesulphonate > *p*-chlorphenyl *p*-chlorbenzenesulphonate > phenyl *p*-chlorbenzenesulphonate > phenyl benzenesulphonate. So far no rule has emerged for the effects of such chlorinations, and it is unlikely that one will be forthcoming until a considerable series of materials has been tested on one mite or its eggs under comparable conditions. Even then, the rule may differ from mite to mite.

The only organophosphorus compound found so far to be superior to parathion is para-oxon which is more toxic also to mammals. E838 is less toxic to mammals but proper evaluation of this is a task for the future.

The existence of ovicidal activity in the two new chlorinated hydrocarbons, aldrin and dieldrin, is encouraging ; it indicates that it may be possible to find a compound of this type which would control both the Fruit Tree Red Spider Mite and Codling Moth.

The ability of at least two chlorinated phenyl benzenesulphonates to permeate leaves is an obvious advantage in greenhouse work where adequate cover of under-surfaces of leaves has always been difficult to achieve. But it should also prove an advantage in the orchard where less thorough spraying may be needed and, hence, a lower gallonage may suffice.

It is relatively easy to understand the killing of aphids sucking sap from leaves into which a toxicant has penetrated from the other side, but the failure of eggs to germinate in such circumstances requires the penetration of the lower cuticle and the egg membranes. It is, of course, true that the summer egg of the Fruit Tree Red Spider Mite has no outer wax layer where it is in contact with the leaf and it should be much easier for a toxicant coming from the leaf to enter than for one applied on the

rest of the egg. Blauvelt and Hathaway (1950) claim that K6451 applied as an aerosol remains as a supercooled liquid for a week or more on the leaf surfaces ; whether this is true for an emulsion painted on is not known but permeation certainly follows. Our formulation crystallized as it dried when painted on glass slides.

Acknowledgements.

The authors are indebted to Mr. R. G. Gambrill for much technical assistance in testing ; to Mr. S. R. B. Solly for the synthesis of a number of compounds ; and for supplies of other chemicals to Dr. B. A. Kilby, Dr. Hubert Martin, Dr. R. A. E. Galley, Messrs. Albright and Wilson Ltd., Monsanto Chemicals Ltd., General Metallurgical and Chemical Ltd., and Plant Protection Ltd.

Summary.

Laboratory tests in 1949 and 1950 against summer forms of the Fruit Tree Red Spider Mite are reported.

Some improvements in the method of testing summer ovicides against this mite have been made.

Two chlorinated hydrocarbons and two fungicides have been shown to possess considerable ovicidal action ; toxaphene has acaricidal action. Chlorinated analogues of benzyl benzoate, benzhydrol and phenyl benzenesulphonate have been tested. The implications of specificity in relation to acaricides and summer ovicides are discussed.

Two chlorinated phenyl benzenesulphonates have been shown to permeate leaves and kill eggs on the opposite side to that painted. This phenomenon is shown by parathion and para-oxon and, to a lesser extent, by azobenzene, but not by bis(*p*-chlorphenyl) methyl carbinol (DMC), nor by diphenyl sulphone (DPS). The advantage of such penetration is emphasized.

Para-oxon exceeds parathion in ovicidal activity, but the dimethyl and di-*iso*propyl homologues of parathion are less ovicidal. The organophosphorus compound E838 shows promise as an ovicide.

References

Armstrong, T. (1950). The residual toxicity of some newer acaricides to the Two-Spotted Spider Mite (Acarina : *Tetranychidae*). *Canad. Ent.*, **82**, 73-83.

Blauvelt, W. E. and Hathaway, W. B. (1950). K6451 Aerosol for Greenhouse Mite control. *Down to Earth*, **5**, 2-4.

Chapman, P. J. and Lienk, S. E. (1950). Orchard mite control experiments in Western New York. *J. econ. Ent.*, **43**, 309-14.

Compton, C. C. and Kearns, C. W. (1937). Improved control of Red Spider on greenhouse crops. *J. econ. Ent.*, **30**, 512-22.

Dean, R. W. (1950). Summer control of orchard mites in Eastern New York. *J. econ. Ent.*, **43**, 167-71.

Eaton, J. K. and Davies, R. G. (1950*a*). The insecticidal activity of some synthetic organophosphorus compounds. *Ann. appl. Biol.*, **37**, 92-104.

—— (1950*b*). The toxicity of certain synthetic organic compounds to the Fruit Tree Red Spider Mite. *Ann. appl. Biol.*, **37**, 471-89.

Grummitt, O. (1950). Di-(*p*-chlorophenyl)methylcarbinol, a new miticide. *Science*, **111**, 361-2.

Kearns, C. W. and Flint, W. P. (1937). Contact insecticidal properties of various derivatives of *cyclo*hexylamine. *J. econ. Ent.*, **30**, 158-66.

Kenaga, E. E. (1949). The toxicity of some substituted phenyl benzoates to the Two-Spotted Spider Mite and Mexican Bean Beetle. *J. econ. Ent.*, **42**, 999-1,000.

——— and Hummer, R. W. (1949). The toxicity of some substituted phenyl benzenesulfonates to the Two-Spotted Spider Mite and Mexican Bean Beetle. *J. econ. Ent.*, **42**, 996-7.

Lathrop, F. H. and Hilborn, M. T. (1950). European Red Mite control. *J. econ. Ent.*, **43**, 172-5.

Metcalf, R. L. (1948). Acaricidal properties of organic compounds related to DDT. *J. econ. Ent.*, **41**, 875-82.

——— and March, R. B. (1949). Studies of the mode of action of parathion and its derivatives and their toxicity to insects. *J. econ. Ent.*, **42**, 721-8.

THE FUNGISTATIC ACTIVITY OF CERTAIN ORGANOPHOSPHORUS INSECTICIDES

By A. H. M. KIRBY and E. L. FRICK

Introduction.

A considerable number of organophosphorus compounds, esters of various phosphorus acids, have now been shown to be insecticidal or acaricidal, and a few, such as HETP, parathion and schradan, have come into commercial use in agriculture and horticulture. No reports have come to our notice, however, regarding the reaction of fungi towards these compounds. If fungi are susceptible, these compounds could play a part at least in control of plant diseases although the non-persistence of some would make them of little account. But for experimental work on pathogenicity of fungi or on control measures, the role played by insecticides or acaricides applied to the host plants needs to be known and, if necessary, allowed for or eliminated. Accordingly, the effect on the spores of two species of fungi, causing Scab on apples and pears respectively, of ten organophosphorus compounds has been examined.

Three types of organophosphorus compound were tested : (*a*) the relatively stable and, hence, persistent type, including parathion and para-oxon ; (*b*) the easily hydrolysed and, therefore, non-persistent type, represented by HETP and TEPP ; and (*c*) the systemic type, of which schradan and bis(dimethylamino)fluorophosphine oxide are best known. All compounds, except HETP and TEPP which were commercial samples, were considered unlikely to contain significant amounts of impurities.

A preliminary experiment was carried out with spores of two strains of *Venturia inaequalis* and three of *V. pirina*. This showed that the variation in susceptibility between strains of the same fungus was unlikely to exceed that within the strain itself. Tests were thereafter carried out on one strain of each fungus, the E_1 strain of *V. inaequalis* and the D_2 strain of *V. pirina*.

Material and methods.

The method of testing was essentially that of Montgomery and Moore (1938).

Compounds of types (b) and (c), being water-soluble, were diluted with water to the requisite concentrations, incorporating 0·005 per cent of a methylated cellulose to facilitate spreading of the sample over the test-slide.

Water-insoluble compounds, type (*a*), were first dissolved in sufficient diacetone alcohol to give a final concentration of this solvent of 2 per cent, adding the emulsifying agent Lissapol N at 0·1 per cent final concentration, and then poured into water. This level of solvent and emulsifier in water was found to cause no inhibition of spores in our series of tests.

The following data for the compounds used are available :

1. *Parathion, O,O-diethyl-O-p-nitrophenyl thionphosphate :* purified by adsorption on alumina; m.p. 6° C.
2. *Para-oxon, O,O-diethyl-O-p-nitrophenyl phosphate :* b.p. 143° C. at 0·007 mm.
3. *O,O-dimethyl-O-p-nitrophenyl thionphosphate :* recrystallized from benzene-petroleum ether ; m.p. 36° C.
4. *O,O-di-isopropyl-O-p-nitrophenyl thionphosphate :* recrystallized from petroleum ether ; m.p. 56-57° C.
5. *O,O-diethyl-O-p-chloro-m-methylphenyl phosphate :* b.p. 100-102° C. at 0·04 mm.
6. *EPN*300, *O-ethyl-O-p-nitrophenyl benzenethionphosphonate :* phosphorus content, calc. 9·60 per cent, found 9·62, 9·65 per cent. P = S content (Schrader's method), 101·25, 101·45 per cent of theory.
7. *HETP :* 20 per cent tetraethyl pyrophosphate.
8. *TEPP :* 40 per cent tetraethyl pyrophosphate.
9. *Schradan, N-octamethyl pyrophosphoryl tetramide :* b.p. 98° C. at 0·002 mm.
10. *Bis(dimethylamino)fluorophosphine oxide :* b.p. 80-81° C. at 10 mm.

Results.

Table I shows the percentages of spores of *V. inaequalis* failing to germinate in contact with various concentrations of the organophosphorus compounds listed above. Figures for the first three compounds are derived from probit regression lines, but for the remaining compounds are the actual figures obtained in tests with the dilutions specified.

TABLE I.

THE PERCENTAGE OF SPORES OF *Venturia inaequalis* (CKE.) WINT., STRAIN E_1, INHIBITED BY VARIOUS ORGANOPHOSPHORUS COMPOUNDS.

Compound.	Percentage concentration.						
	0·001	0·01	0·025	0·05	0·1	0·2	1·0
Parathion	nil	16	99	—	—	—	—
Para-oxon	nil	18	62	90	98	—	—
Dimethyl homologue of parathion	nil	nil	46	89	99	—	—
Di-*iso*propyl homologue of parathion	nil	6	—	—	21	—	26
p-Chloro-*m*-methyl analogue of para-oxon	nil	20	59	100	—	—	—
EPN300	—	—	—	—	—	nil	—
HETP	—	—	nil	64	100	—	—
TEPP	nil	17	43	—	100	—	—
Schradan	—	—	—	—	—	—	nil
Bis(dimethylamino)fluorophosphine oxide	—	—	—	—	—	—	nil

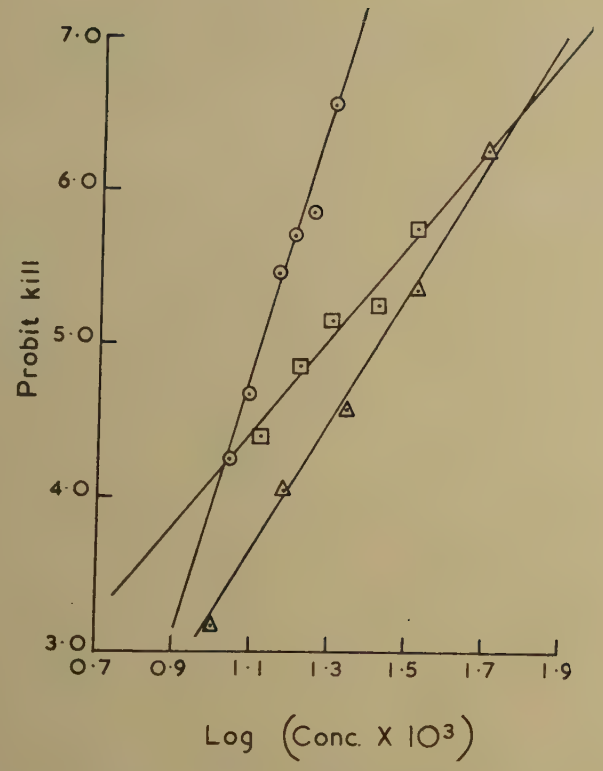
Table II shows the corresponding results for spores of *V. pirina* ; figures for the first three compounds are again derived from probit regression lines.

TABLE II.

THE PERCENTAGE OF SPORES OF *Venturia pirina* ADERH., STRAIN D_2, INHIBITED BY VARIOUS ORGANOPHOSPHORUS COMPOUNDS.

Compound.	Percentage concentration.						
	0·001	0·01	0·025	0·05	0·1	0·2	1·0
Parathion	nil	35	90	100	—	—	—
Para-oxon	nil	28	95	100	—	—	—
Dimethyl homologue of parathion	nil	21	84	100	—	—	—
Di-*iso*propyl homologue of parathion	nil	33	—	—	53	—	56
p-Chloro-*m*-methyl analogue of para-oxon	nil	37	52	100	—	—	—
EPN300	—	—	—	—	—	nil	—
HETP	nil	52	97	100			
TEPP	nil	54	—	100	—	—	—
Schradan	—	—	—	—	—	—	nil
Bis(dimethylamino)fluorophosphine oxide	—	nil	—	—	10	—	64

The results shown in Tables I and II indicate that further exploration was unnecessary in the case of the systemic insecticides or in the case of the di-*iso*propyl homologue of parathion. As the unstable compounds, HETP and TEPP, were impure materials no attempt was made to obtain further data. EPN 300 was also ineffective, and it was decided to ignore the *p*-chlor-*m*-methyl analogue of para-oxon as this was found of no value as an acaricide by Kirby and McKinlay (1951) and was unlikely to come into general use. Further tests were therefore confined to parathion and its dimethyl homologue and to para-oxon, using concentrations suitable for constructing probit regression lines. The lines obtained for these three compounds against *V. inaequalis* spores are shown in Fig. 1 ; the corresponding lines for *V. pirina* are given in Fig. 2. From these, the ED_{50} (median effective dose) values have been calculated. It is evident that a straight line regression does not fit the probit values obtained for the dimethyl homologue of parathion against *V. pirina* ; the deviation of these values from the straight line is shown by a highly significant value for χ^2. The regression would best be represented by a curve.

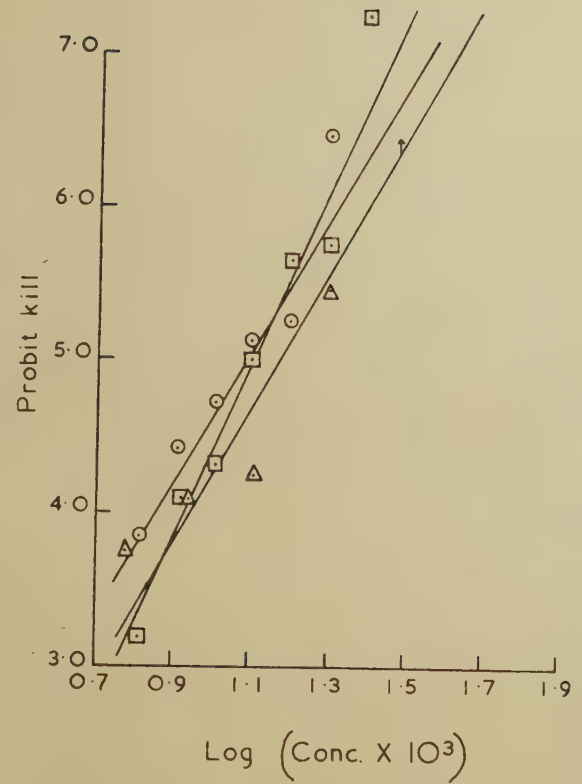


Equations of probit lines.	Log (ED_{50} × 10^3).	ED_{50} per cent.
○ y = 8·28 x − 4·28	1·12 (S.E. 0·03)	0·0132
□ y = 3·06 x + 1·06	1·30 (S.E. 0·02)	0·0196
△ y = 4·12 x − 0·86	1·42 (S.E. 0·01)	0·0265

FIG. 1.

Venturia inaequalis (Cke.) Wint. *Strain* E_1.

○ Parathion, slope (b) = 8·28 (S.E. 0·23).
□ Para-oxon, slope (b) = 3·06 (S.E. 0·44).
△ Dimethyl homologue of parathion, slope (b) = 4·12 (S.E. 0·30).



Equations of probit lines.	Log (ED_{50} × 10^3).	ED_{50} per cent.
○ y = 4·20 x + 0·44	1·09 (S.E. 0·01)	0·0122
□ y = 5·53 x − 1·14	1·11 (S.E. 0·02)	0·0129
△ y = 4·38 x − 0·20	1·19 (S.E. 0·43)	0·0154

FIG. 2.

Venturia pirina Aderh. *Strain* D_2.

○ Parathion, slope (b) = 4·20 (S.E. 0·41).
□ Para-oxon, slope (b) = 5·53 (S.E. 0·76).
△ Dimethyl homologue of parathion, slope (b) = 4·38 (S.E. 1·41).
↑ Point at which 100 per cent inhibition occurred.

Nature of fungitoxic action.

Tests were carried out with parathion and para-oxon to determine whether the action of these compounds was fungicidal or fungistatic. Spores were treated for 24 hours with concentrations of these compounds known to produce 100 per cent inhibition of germination. The spores were then centrifuged off and well washed to remove the toxicant, and finally suspended in nutrient medium to allow germination to occur as it did in controls. The germination of all spores was normal, and there was no evidence that germination was delayed. It can be concluded, therefore, that the action of these organophosphorus compounds is purely fungistatic.

Discussion.

These experiments show that a number of the organophosphorus insecticides have a marked fungistatic action upon the organisms causing apple and pear scab. Indeed, the only compounds, out of ten tested, which failed to show activity were the relatively weak systemic insecticide, schradan, and the new persistent insecticide, EPN300. Presumably, either of these could be used for control of pests on plants being used for tests involving either of these fungi. The remainder are all open to objection even when used at 0·01 per cent, except the second systemic, bis(dimethylamino)fluorophosphine oxide, which seems to be safe for such use on apple and only objectionable on pear at concentrations of 0·1 per cent or higher.

Apart from the difference in reaction to bis(dimethylamino)fluorophosphine oxide and to TEPP, the responses are very similar by both species to any one compound. This is very true for parathion which has an ED_{50}, i.e. the dose inhibiting germination of 50 per cent of the spores, against *V. inaequalis* of 0·0132 per cent and against *V. pirina* of 0·0122 per cent ; the ED_{95} values would differ rather more, being rather less than 0·025 per cent for the former fungus and rather more for the latter. The ED_{50} values for the dimethyl homologue of parathion are 0·0265 per cent and 0·0154 per cent respectively, but the regression lines have the same slope for both organisms ; in the case of *V. pirina*, the line is very nearly parallel to that of parathion. On the other hand, the toxicity of the di-*iso*-propyl homologue of parathion toward either species changes very little with concentration, leading to a remarkably low slope.

Para-oxon has a lower slope than parathion against *V. inaequalis* but higher against *V. pirina*, so that neither the relative potencies nor the relative rates of penetration seem to be involved alone. The *p*-chlor-*m*-methyl analogue shows remarkably similar toxicity values to those for para-oxon against both fungi, indicating that a *p*-nitro group is not essential. The insecticidal activity of *p*-chlor-analogues is markedly less than that of corresponding *p*-nitro-compounds (Metcalf and March, 1949). The total lack of fungitoxicity in EPN300 is striking in this connection ; the toxicity of this compound toward flies and bees is of the same order as those of parathion and para-oxon (Metcalf and March, 1949).

HETP and TEPP exhibited a sharp increase in toxicity with increase in concentration, but both are more toxic to spores of *V. pirina* than to those of *V. inaequalis*. In fact, total inhibition of germination of spores of *V. pirina* could be expected at concentrations of these products normally used in the field. However, as neither product is stable for more than a day or so, it is clear that such fungistatic action would avail the grower little. It could have been expected that, as TEPP contains twice as much tetraethyl pyrophosphate as does HETP, that the former would have been more effective than the latter. In fact, only in the case of *V. inaequalis* spores did this occur and even there, as in the case of the other species, the ED_{95} value would appear to be the same for either product. The complex nature of these products makes any attempt to interpret these results unprofitable.

Parathion and its dimethyl homologue are sufficiently closely related for parallel regression lines to be expected. In practice, the slopes differ appreciably in the case of *V. inaequalis* and the parallelism in the case of *V. pirina* may, as already noted, be spurious. As the test procedure was identical for all tests, variations in the application of the toxicants cannot account for the changes in slope. Some other factor, such as the relative rates of hydrolysis of the two esters in the spore suspension, must be involved.

The non-parallelism of the lines for parathion and its oxygen analogue, para-oxon, is perhaps less surprising. It is instructive to note that in the dosage mortality curves for parathion and the analogue containing an ortho-chlorine atom on the benzene ring, published by Magee and Gaines (1950), using the cotton boll weevil as test organism, the slope of the analogue line is considerably less than that of parathion. With regard to the work reported in this paper, it seems likely that the stability of the compounds will not be identical, but that the ester linkages may hydrolyse at different rates. Peck (1948) has reported parathion to be soluble in water at 20° C. to the extent of 15 p.p.m. and to undergo 50 per cent hydrolysis by 120 hours, but no data are available for para-oxon or the other

compounds tested. It is an interesting speculation that the lack of toxicity of EPN300 may lie in the greater stability of the benzene-phosphorus bond. The release of *p*-substituted phenol from several of the compounds tested is unlikely to be the sole explanation of their toxicity as no such product could be released from HETP or TEPP which show considerable activity. On the other hand, the present evidence favours the view that the effects are produced by hydrolysis products rather than by the intact molecules employed.

Acknowledgements.

The authors wish to express their thanks to Mr. D. S. Kirkham for isolates of the fungi concerned, and Mr. W. R. Stanton, of the John Innes Horticultural Institution, who drew their attention to the problem. They also wish to thank Dr. B. A. Kilby, School of Medicine, Leeds, for the samples of compounds 2, 5, 9 and 10, and Messrs. Albright and Wilson, Ltd., for the samples of compounds 1, 3, 4, 6, 7 and 8.

Summary.

1. A number of organophosphorus compounds have been tested against spores of *Venturia inaequalis* (Cke.) Wint. and *V. pirina* Aderh.

2. Three types of compound were examined : (*a*) sparingly soluble in water and relatively persistent ; (*b*) easily soluble in water and non-persistent ; (*c*) systemic.

3. All types contain compounds inhibiting germination of spores of one or both of these two fungi, but EPN300 of type (*a*) and schradan of type (*b*) were inactive at all concentrations tested.

4. Tests showed those compounds which were inhibitory to be fungistatic and not fungicidal.

5. Dosage-mortality curves have been plotted for parathion, its dimethyl homologue and paraoxon, and the ED_{50} values derived, for both fungi.

6. The implications for fungitoxicity and pathogenicity trials involving these fungi are discussed.

References

Kirby, A. H. M. and McKinlay, K. S. (1951). Laboratory experiments on the toxicity of potential acaricides. *Rep. E. Malling Res. Sta. for 1950*, 164-71.

Magee, W. J. and Gaines, J. C. (1950). Toxicity of phosphorus compounds to various insects. *J. econ. Ent.*, **43**, 281-6.

Metcalf, R. L. and March, R. B. (1949). Studies of the mode of action of parathion and its derivatives and their toxicity to insects. *J. econ. Ent.*, **42**, 721-8.

Montgomery, H. B. S. and Moore, M. H. (1938). A laboratory method for testing the toxicity of protective fungicides. *J. Pomol.*, **15**, 253-66.

Peck, D. R. (1948). Alkali stability of the insecticide E605. *Chem. and Industr.*, 526.

EXPERIMENTS ON INCREASING THE PENETRATION OF OVICIDES AND INSECTICIDES

By K. S. McKINLAY, A. H. M. KIRBY and M. ALLEN

Introduction.

A considerable proportion of insects and mites of economic importance are controlled by contact insecticides, such as derris or DDT ; and it is probably true to say that where control is achieved in the egg stage, the ovicide is always a contact poison. The penetration of the outer layer or layers of the insect cuticle or egg shell is an essential prerequisite for toxic action on any of the vital processes within. A successful toxicant achieves penetration by virtue of its own structure, and it is usually considered that any contact insecticide or ovicide must have a considerable degree of lipoid solubility to enable it to cross the lipoid layers of the cuticle or egg shell. All the chlorinated hydrocarbon insecticides, for example, possess marked lipoid solubility, but it is not always certain which portion of the molecule is responsible for this power of penetration.

The possibility exists that the addition of a second chemical, having no toxicity *per se* but having a special capacity for penetrating lipoid membranes and also being a good solvent for a given insecticide, might enhance the penetration, and hence the toxic action, of the insecticide. In this way, it might be possible to cause adequate mortality of a pest with much lower quantities of insecticide or ovicide ; if the toxicant were expensive compared with the penetrating agent (hereafter called penetrant), this would lead to a reduced cost of application. Moreover, it might be possible to introduce toxicants which had poor powers of penetration, or even none at all, and which would otherwise be useless.

An observation by Craufurd-Benson and MacLeod (1945) that body lice, normally resistant to derris, died rapidly when high-boiling tar acids were added was followed up by Webb and Green (1945) who demonstrated that cresylic acid caused a similar increase in toxicity of diphenylamine toward sheep keds. These workers made a systematic study of the factors involved, using diphenylamine as a low-grade toxicant and a considerable range of solvents. It was found possible to divide the twenty solvents used into four groups showing high, medium, low or nil carrier efficiency respectively. Some four properties appeared to be requisite for high carrier efficiency ;

(1) a high rate of penetration through beeswax,
(2) a sufficiently high partition coefficient between beeswax and water,
(3) a solubility of the toxicant in the solution of solvent in water, and
(4) a boiling-point above 190° C.

The five solvents giving the best performance were the ortho-, meta- and para-cresols, xylenol (b.p. 216-7° C.) and benzyl alcohol.

In selecting one of these for work with pests of fruit, it was considered that benzyl alcohol would be least phytotoxic and work was therefore commenced with this solvent. Some work was also done with carbitol (diethylene glycol monoethyl ether) which Webb and Green found to be of low carrier efficiency. Tests were carried out with three overwintering eggs, those of the insects *Aphis pomi* Deg. and *Operophtera brumata* L. and of the mite *Metatetranychus ulmi* (Koch) ; the summer eggs of this mite were also used. Experiments were also carried out using the convenient laboratory test-insect, *Tribolium confusum* Duv.

EXPERIMENTS WITH WINTER EGGS.

Fruit Tree Red Spider Mite.

The winter eggs of this pest are notoriously difficult to kill, even 3 per cent petroleum emulsion sometimes failing to cause 100 per cent mortality in the field. Eaton and Davies (1950*b*) have shown that two synthetic organic compounds will give a complete kill by a laboratory dipping technique : *n*-dodecyl thiocyanate at 0·2 per cent pure ingredient, and azoxybenzene at the same strength. These workers obtained a mortality of only 25 per cent with 0·2 per cent azobenzene. These three compounds were selected for test, together with three others : diphenylamine, in view of the work of Webb and Green, bis (*p*-chlorphenyl) methyl carbinol (DMC), and diphenyl sulphone (DPS), both of which had been shown by Eaton and Davies (1950*b*) to be highly ovicidal toward the summer egg of this mite.

The techniques used, both for this egg and the others employed in this series of experiments, were those described by Eaton and Davies (1950*a*), which ensured the use of eggs laid in the previous autumn.

Benzyl alcohol as a penetrant.

DMC, dodecyl thiocyanate and azoxybenzene were formulated by dissolving in acetone together with an emulsifying agent and a wetting agent ; when poured into sufficient water, this formulation yielded a solution containing 2 per cent acetone, 0·05 per cent *cyclo*hexylamine dodecyl sulphate (MB320), and 0·02 per cent di-octyl sodium sulphosuccinate (Aerosol OT). This formulation also gave a stable emulsion when 2·5 per cent benzyl alcohol was added. However, although DPS, azobenzene and diphenylamine alone could be formulated in the same way, when 2·5 per cent benzyl alcohol was present stable emulsions were only formed when the formulation was changed to 9 per cent acetone, 0·1 per cent MB320 and 0·04 per cent Aerosol OT. Neither of these formulations *per se* caused any appreciable mortality of eggs. The percentage mortalities, corrected by Abbott's formula, are recorded in Table I.

TABLE I.

PERCENTAGE MORTALITY OF WINTER EGGS OF THE FRUIT TREE RED SPIDER MITE WHEN DIPPED IN EMULSIONS OF VARIOUS OVICIDES, WITH AND WITHOUT BENZYL ALCOHOL, 1949.

Toxicant, per cent.		Benzyl alcohol, per cent.	Percentage mortality (c = o).
n-Dodecyl thiocyanate	0·05	—	0·0
do.	0·05	2·5	100·0
Azobenzene	0·2	—	2·3
do.	0·2	2·5	100·0
Azoxybenzene	0·025	—	0·0
do.	0·2	—	95·9
do.	0·025	2·5	99·5
Diphenylamine	0·2	—	2·9
do.	0·2	2·5	77·4
Bis(*p*-chlorphenyl) methyl carbinol (DMC)	0·05	—	48·3
do.	0·05	2·5	88·2
Diphenyl sulphone (DPS)	0·2	—	10·9
do.	0·2	2·5	4·4
Nil		2·5	0·0

It will readily be seen from Table I that in all cases, except that of DPS, the addition of 2·5 per cent benzyl alcohol caused a pronounced increase in mortality, although, in the absence of a toxicant, benzyl alcohol at this concentration caused no mortality. In the case of azoxybenzene, it can be seen that the same high mortality could be achieved with one-eighth the amount of toxicant when the penetrant was added. It is clear, therefore, that benzyl alcohol can act as a carrier or penetrant for a number of ovicides with respect to the winter egg of the Fruit Tree Red Spider Mite, leading to full toxicity with quantities of toxicant inactive when employed alone. The relatively small increase in toxicity when benzyl alcohol was added to DMC and the failure to enhance the slight activity of DPS indicate, however, that although materials may be highly ovicidal toward the summer eggs, they will not necessarily be rendered good winter ovicides merely by adding this penetrant.

These experiments were repeated and extended in 1950, in order to discover what concentration of benzyl alcohol was required to increase appreciably the effectiveness of various toxicants. To this end, three of the four toxicants previously shown to respond well were tested with three concentrations of benzyl alcohol (Table II) ; the fourth toxicant was subjected to a more exhaustive test in which four concentrations of toxicant and four of benzyl alcohol were employed (Table III). The technique employed for dipping was the same as before, and the formulation used was 2 per cent acetone, 0·05 per cent MB320 and 0·02 per cent Aerosol OT. The sample of alkyl thiocyanates, manufactured from synthetic C_{12}-C_{13} alcohols, used in the previous season, was purified by fractional distillation under reduced pressure and the fraction distilling between 110°-120° C. at 0·3 mm. collected. Commercial diphenylamine was recrystallized first from isopropanol and secondly from petroleum ether, b.p. 60°-80° C., to give material melting at 55°-55·5° C. Commercial azobenzene was crystallized twice from petroleum ether, b.p. 40°-60° C., to yield crystals melting at 68°-69° C. Commercial azoxybenzene was

purified by dissolving in petroleum ether, b.p. 60°-80° C., and passing the solution through sufficient alumina to remove dark-coloured impurities ; the orange-yellow filtrate was concentrated and the precipitate recrystallized from 96 per cent ethanol to yield very pale yellow crystals, m.p. 36° C.

The concentrations used of toxicants and of benzyl alcohol, together with the corrected percentage mortalities are recorded in Tables II and III.

TABLE II.

PERCENTAGE MORTALITY OF WINTER EGGS OF THE FRUIT TREE RED SPIDER MITE WHEN DIPPED IN EMULSIONS OF VARIOUS OVICIDES, WITH AND WITHOUT BENZYL ALCOHOL, 1950.

Toxicant, per cent.		Benzyl alcohol, per cent.	Percentage mortality (c = o).
n-Dodecyl thiocyanate	0·05	—	8·3
do.	0·05	2·0	93·3
do.	0·05	1·0	49·5
do.	0·05	0·5	18·1
Diphenylamine	0·2	—	20·9
do.	0·2	5·0	86·5
do.	0·2	2·5	24·3
do.	0·2	1·25	0·0
Azobenzene	0·2	—	19·3
do.	0·2	2·0	99·4
do.	0·2	1·0	39·3
do.	0·2	0·5	31·7

It is clear from Table II, that the penetrant or carrier action of benzyl alcohol is confirmed for all three toxicants, but whereas the use of 5 per cent penetrant failed to give complete mortality when 0·2 per cent diphenylamine was used, the use of 2 per cent was adequate with 0·2 per cent azobenzene and a distinct increase in toxicity resulted with this ovicide when only 0·5 per cent penetrant was added.

The data in Table III indicate that a practically complete kill of eggs can be achieved with as little as 0·00625 per cent azoxybenzene if 5 per cent benzyl alcohol be added, although neither the penetrant nor the toxicant used alone gave any kill at these concentrations. Conversely, the addition of only 1·25 per cent benzyl alcohol to 0·05 per cent azoxybenzene led to an almost complete kill of eggs. If the concentration of benzyl alcohol is reduced below 1 per cent, the penetrant has no useful effect even with this ovicide, the most effective *per se* so far tried. The cost of benzyl alcohol is too great to allow of its use in the field at higher concentrations.

TABLE III.

PERCENTAGE MORTALITY (c = o) OF WINTER EGGS OF THE FRUIT TREE RED SPIDER MITE WHEN DIPPED IN EMULSIONS OF AZOXYBENZENE, WITH OR WITHOUT BENZYL ALCOHOL.

Azoxybenzene, per cent.	Benzyl alcohol, per cent.				
	Nil.	0·625	1·25	2·5	5·0
Nil	—	0·0	0·0	3·8	0·8
0·00625	0·0	0·0	0·0	32·2	100·0
0·0125	0·0	0·0	0·0	97·9	98·3
0·025	0·0	7·2	34·8	100·0	100·0
0·05	0·0	23·5	98·9	100·0	100·0

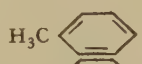
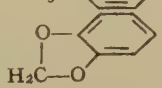
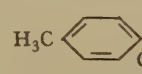
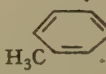
Structure in relation to penetrant activity.

The need to find either cheaper or more potent penetrants led us to investigate compounds related to benzyl alcohol in general structure. The five compounds found by Webb and Green to promote penetration of ovicides were all closely related and consisted of a lipophilic benzene nucleus, with one or more short alkyl side-chains, and a hydrophilic hydroxyl group either directly attached to the nucleus, as in the three cresols and xylenol, or separated only by a single carbon atom as in benzyl alcohol. It is possible that only molecules having this compact, non-polar-polar structure can function as penetrants and the first step in investigating such structure-activity relationships is to modify the benzyl alcohol molecule in various ways to see if the biological action is enhanced or reduced.

The first type of modification tried consists in separating the polar and non-polar parts of the molecule by longer chains ; this led to the testing of β-phenylethyl alcohol and 3-phenylpropyl alcohol. Alkyl groups may also be added to the non-polar end of the molecule, and *p*-tolyl-carbinol was therefore prepared and tested. Another variant of this type having particular interest is piperonyl alcohol, which is a part of piperonyl butoxide, now well known as a synergist or " extender " for pyrethrum and also rotenone (Wachs, 1947). The other end of the butoxide molecule, ethylene glycol monobutyl ether (butyl cellosolve), was also tested. The effect of replacing the hydroxyl group by an amino group was tested in β-phenylethylamine ; the branched-chain isomeric α-phenylethylamine was also included, and a short-chain molecule bearing both amino and hydroxyl groups, monoethanolamine. Finally one xylenol, 2,4-xylen-1-ol, and a substituted cresol, benzyl cresol, were tested. The structural relationships of benzyl alcohol and these ten compounds are depicted in Table IV, together with those of four other compounds used in another test described later in this paper.

TABLE IV.

FORMULAE AND PHYSICAL DATA FOR COMPOUNDS TESTED FOR PENETRANT ACTION ON THE WINTER EGGS OF THE FRUIT TREE RED SPIDER MITE.

Compound.	Structural formula.	Melting point, °C.	Boiling point, °C.	Index of refraction.
Benzyl alcohol		—	198	$\mu_D^{20} = 1{\cdot}5387$
β-Phenylethyl alcohol ..		—	212	$\mu_D^{16} = 1{\cdot}5323$
3-Phenylpropyl alcohol ..		—	223	$\mu_D^{16} = 1{\cdot}5258$
p-Tolyl carbinol		60	—	—
Piperonyl alcohol		55	—	—
β-Phenylethylamine		—	142-3	$\mu_D^{16} = 1{\cdot}5321$
α-Phenylethylamine		—	187	$\mu_D^{16} = 1{\cdot}5278$
Monoethanolamine	$HOCH_2CH_2NH_2$	—	164	$\mu_D^{16} = 1{\cdot}4556$
Butyl cellosolve	$HOCH_2CH_2OC_4H_9$	—	165	$\mu_D^{19} = 1{\cdot}4207$
2,4-Xylen-1-ol		—	209	$\mu_D^{16} = 1{\cdot}5387$
p-Benzyl-*m*-cresol			187-196 at 26 mm.	$\mu_D^{16} = 1{\cdot}5922$
Benzylamine		—	183	$\mu_D^{18} = 1{\cdot}5442$
Methyl benzoate		—	197	$\mu_D^{18} = 1{\cdot}5188$
Quinoline		—	235	$\mu_D^{18} = 1{\cdot}6208$
m-Cresol		—	199	$\mu_D^{18} = 1{\cdot}5397$

The ten new compounds were used without further purification ; physical data obtained on them are included in Table IV. The standard ovicide used was azoxybenzene at 0·03 per cent which was expected to cause a low mortality in the absence of a penetrant. The compounds were tested, with and without azoxybenzene, employing a concentration of 2 per cent in all cases. Formulation was in 2 per cent acetone with 0·05 per cent MB320 and 0·02 per cent Aerosol OT. The results are set out in Table V.

TABLE V.

PERCENTAGE MORTALITY (c = 0) OF WINTER EGGS OF THE FRUIT TREE RED SPIDER MITE WHEN DIPPED IN 2 PER CENT EMULSIONS OF VARIOUS POTENTIAL PENETRANTS, WITH AND WITHOUT AZOXYBENZENE.

Potential penetrant (2 per cent).	In absence of azoxybenzene.	In presence of 0·03 per cent azoxybenzene.
Benzyl cresol	100·0	100·0
2,4-Xylen-1-ol	0·0	100·0
β-Phenylethyl alcohol	0·0	100·0
3-Phenylpropyl alcohol	0·0	100·0
p-Tolyl carbinol	0·0	97·5
Piperonyl alcohol	0·0	100·0
β-Phenylethylamine	0·0	100·0
α-Phenylethylamine	0·0	28·3
Monoethanolamine	0·0	43·6
Butyl cellosolve	5·9	59·3
Nil	—	71·5

It will be immediately apparent that 0·03 per cent azoxybenzene alone gave a much higher kill than was expected, and the value of any of these compounds compared with that of benzyl alcohol cannot be assessed. It is, however, possible to separate them into two classes, those which enhanced the toxicity of the ovicide and those which did not. Seven compounds fall in the first class and, of these, only benzyl cresol was highly toxic *per se* at the concentration used. The other three compounds, although themselves non-toxic at 2 per cent, appear to have reduced the toxicity of the ovicide, presumably by reducing the amount of toxicant passing through the lipoid layer. In the cases of monoethanolamine and butyl cellosolve, the absence of a sufficiently large non-polar group in the molecule may well reduce the lipoid solubility too far ; the failure of α-phenylethylamine suggests that a branched chain between the polar and non-polar parts of the molecule is inimical to success as a penetrant. It is true, of course, that all three compounds possess a boiling point below 190° C. which was regarded by Webb and Green as necessary for high carrier efficiency. But β-phenylethylamine, which was effective, had the lowest boiling-point of any compound tested, although the other successful compounds all boil above 190° C., two even being solid at room temperatures. 2,4-Xylen-1-ol was expected to act as a penetrant by analogy with Webb and Green's work, but the success achieved with β-phenylethyl alcohol and the even longer 3-phenylpropyl alcohol is quite interesting. Similarly, it is clear that a short chain or even a methylenedioxy ring can be introduced on the non-polar portion of the benzyl alcohol molecule without destroying its efficiency. It will be desirable to see how far these modifications can be pursued, as well as to get a better indication of the relative activities of the various penetrants.

Webb and Green used diphenylamine, which is a weak base, as their toxicant, and it is notable that, of the five best penetrants in their series, four are phenolic in character and the other, benzyl alcohol, is neutral. A number of penetrant-toxicant pairs of which the character would be varied from basic-basic to acidic-acidic were therefore tested. Two experiments were carried out. In the first, benzyl alcohol and benzylamine were used as penetrants, and 4,6-dinitro-*o*-cresol (DNOC) and diphenylamine as ovicides. All four compounds were tested alone at two concentrations, and then repeated in pairs. Formulation was as before ; the results are set out in Table VI.

In the second experiment, DNOC and diphenylamine were again used as toxicants, but *m*-cresol, one of Webb and Green's best penetrants, and quinoline, a moderate penetrant for the sheep ked, and methyl benzoate, which was useless in their tests, were used. Moreover, only one concentration was used of each alone and in pairs, although formulation was unaltered. Results are given in Table VII.

From Table VII it is clear that, at 2 per cent, *m*-cresol killed half the eggs and quinoline nearly all ; the other penetrant, methyl benzoate, was only slightly toxic. But while the kill in the presence

TABLE VI.

PERCENTAGE MORTALITY (C = 0) OF WINTER EGGS OF THE FRUIT TREE RED SPIDER MITE WHEN DIPPED IN EMULSIONS OF OVICIDES AND/OR PENETRANTS CHOSEN FOR ACIDIC OR BASIC CHARACTER.

Ovicide and concentration, per cent.	No penetrant.	Benzyl alcohol, per cent.		Benzylamine, per cent.	
		1·5	3·0	1·5	3·0
DNOC, 0·05	44·7	68·1	94·5	17·7	13·4
DNOC, 0·2	58·8	65·6	73·1	56·3	62·3
Diphenylamine, 0·1 ..	2·9	36·8	66·0	9·3	16·2
Diphenylamine, 0·2 ..	9·6	91·3	61·5	39·5	33·3
No ovicide	—	9·9	8·1	0·0	2·3

TABLE VII.

PERCENTAGE MORTALITY (C = 0) OF WINTER EGGS OF THE FRUIT TREE RED SPIDER MITE WHEN DIPPED IN 2 PER CENT EMULSIONS OF OVICIDES AND/OR PENETRANTS CHOSEN FOR ACIDIC OR BASIC CHARACTER.

Ovicide, 2 per cent.	No penetrant.	*m*-Cresol, 2 per cent.	Quinoline, 2 per cent.	Methyl benzoate, 2 per cent.
DNOC	1·8	100·0	95·2	86·3
Diphenylamine ..	18·7	96·8	97·3	15·7
No ovicide	—	51·9	95·7	5·9

of *m*-cresol increases definitely for either toxicant, there is no evidence that the toxicity of quinoline plus either toxicant was greater than that of the quinoline alone. In the presence of methyl benzoate, the toxicity of DNOC was greatly enhanced but that of diphenylamine was unaffected. From Table VI it can be seen that neither benzyl alcohol nor the amine were toxic *per se*, even at 3 per cent. But, while benzyl alcohol acted as a penetrant for both DNOC and diphenylamine, benzylamine seems to have enhanced the kill due to the latter toxicant only. There is, therefore, no evidence from these experiments that pairs should be acidic-acidic, basic-basic or mixed. The effective penetrants, *m*-cresol and benzyl alcohol, worked for either the acidic or the basic toxicant ; quinoline cannot be judged, and the other two compounds succeeded in enhancing the activity of only one toxicant each. Some compounds appear to affect a wider range of toxicants than others.

Green Apple Aphid.

Tests were made with the overwintering eggs of this aphid with, in the first year, two penetrants from Webb and Green's list, benzyl alcohol and carbitol (diethylene glycol monoethyl ether). The toxicant used was alkyl thiocyanate containing 48 per cent of the *n*-dodecyl ester. The formulation was as described early in this paper ; results are shown in Table VIII.

TABLE VIII.

PERCENTAGE MORTALITY (C = 0) OF EGGS OF THE GREEN APPLE APHID WHEN DIPPED IN EMULSIONS OF ALKYL THIOCYANATE, C_{12}-C_{13}, WITH OR WITHOUT BENZYL ALCOHOL OR CARBITOL.

Alkyl thiocyanate, per cent.	No penetrant.	Benzyl alcohol, per cent.			Carbitol, per cent.		
		1·25	2·5	5·0	1·25	2·5	5·0
0·1	10	19	62	97	5	0	13
0·05	1	12	28	84	12	4	12
Nil	—	12	21	93	18	21	28

Although 0·1 per cent alkyl thiocyanate proved to be a suitable level of toxicant to show the effect of a penetrant, little effect was apparent due to either compound tested. At 5 per cent, benzyl alcohol alone was highly toxic and carbitol much less toxic ; in both cases, toxicity fell sharply with concentration. The combinations of toxicant with benzyl alcohol caused little more mortality than that to be expected from the combined activities of the individual compounds. With carbitol, the mortality due to combined treatments was less in each case than that to be expected from the carbitol alone. It can be concluded that neither benzyl alcohol nor carbitol function as penetrants for alkyl thiocyanate in the case of this egg, and that in the case of carbitol the two compounds antagonize rather than synergise one another.

In a second year's trials, eggs of this aphid were dipped in parathion formulated in the same way. The percentage mortality (c = o) for 0·01 per cent parathion alone was 73·8 ; when 2 per cent benzyl alcohol was added, mortality remained at 73·5 per cent. The mortality due to 2 per cent benzyl alcohol alone was 4·5 per cent. There is, therefore, no evidence that benzyl alcohol acts as a penetrant for this ovicide in the case of the winter eggs of the Green Apple Aphid.

Winter Moth.

The overwintering eggs of this pest were dipped in parathion, formulated as above, at 0·01 per cent. The corrected mortality was 98·3 per cent, which rose to 99·6 per cent in the presence of 2 per cent benzyl alcohol. As, however, 2 per cent benzyl alcohol alone caused a mortality of 31·4 per cent, there was no evidence that any penetrant effect had been exerted.

EXPERIMENTS WITH SUMMER EGGS.

The Fruit Tree Red Spider Mite.

Although these eggs are susceptible to a larger range of toxicants than are the winter eggs (Eaton and Davies, 1950*b*), no entirely satisfactory ovicide has yet been found for field use. It is therefore desirable to find an extender which may be safely used in conjunction with compounds known to possess considerable toxicity. A trial was therefore carried out with benzyl alcohol as potential penetrant, and two ovicides, parathion and azobenzene. Formulation was as described earlier ; results are given in Table IX.

The results are remarkably similar to those obtained on the winter eggs of *Aphis pomi* and the Winter Moth, but quite different from those obtained on the winter eggs of the mite. Although benzyl alcohol itself proved toxic, it lowered the toxicity due to either ovicide alone. There seems, therefore, little hope that benzyl alcohol will prove valuable in enhancing the activity of summer ovicides against this pest.

Two other compounds were tried for possible penetrant action : hexylene glycol and the well-known synergist for pyrethrum and rotenone, piperonyl butoxide. These were formulated as before, and the results are set out in Table X.

TABLE IX.

PERCENTAGE MORTALITY (c = o) OF SUMMER EGGS OF THE FRUIT TREE RED SPIDER MITE WHEN DIPPED IN EMULSIONS OF PARATHION OR AZOBENZENE, WITH OR WITHOUT BENZYL ALCOHOL.

Ovicide and concentration, per cent.	No penetrant.	Benzyl alcohol, per cent.			
		0·125	0·25	0·5	2·0
Parathion, 0·025 ..	51·6	30·1	19·3	24·3	45·7
Azobenzene, 0·01 ..	85·3	74·0	—	74·6	69·6
No ovicide	—	8·1	—	27·1	52·7

These results indicate that these compounds are of no value as penetrants for azobenzene, at least, against these summer eggs. The mortality due to either combined spray is less than the arithmetical sum of the mortalities due to the components.

TABLE X.

PERCENTAGE MORTALITY OF SUMMER EGGS OF THE FRUIT TREE RED SPIDER MITE WHEN DIPPED IN EMULSIONS OF AZOBENZENE, WITH OR WITHOUT HEXYLENE GLYCOL OR PIPERONYL BUTOXIDE.

Ovicide, per cent.	Penetrant, per cent.	Percentage mortality (c = 0).
Azobenzene, 0·01	Hexylene glycol, 1·0	58·7
Nil	do.	4·5
Azobenzene, 0·01	Piperonyl butoxide, 1·0	80·5
Nil	do.	25·2
Azobenzene, 0·01	Nil	72·1

EXPERIMENTS WITH AN ADULT INSECT.

As Webb and Green experimented with an active insect, the sheep ked, it was considered desirable to extend the work to another. For this purpose adults of the Confused Flour Beetle, *Tribolium confusum* Duv. were used, employing five replicates of twenty insects at each concentration. One penetrant, benzyl alcohol, was tested at various concentrations, and two insecticides, diphenylamine and parathion, were used in tests with dusts ; parathion and benzyl alcohol, formulated as above, were also used for a spraying test.

Dusts were prepared by dissolving the requisite amounts of insecticide and/or penetrant in acetone and adding the solution to 1 gm. of celite (Hyflo Supercel) in a 3 inch × 1 inch glass tube. The solvent was evaporated and the insects placed on the remaining dust. Tests were made in which the toxicant level was kept constant and the penetrant level varied, and vice-versa. Results for diphenylamine are set out in Tables XI and XII ; counts were made after 95 hours.

TABLE XI.

PERCENTAGE MORTALITY OF *Tribolium confusum* ADULTS ALLOWED TO WALK ON DUSTS CONTAINING DIPHENYLAMINE AND/OR BENZYL ALCOHOL.

Diphenylamine, per cent.	Benzyl alcohol, per cent.	Percentage mortality (c = 0).
0·0	8·0	0
2·5	0·0	22
2·5	0·08	29
2·5	0·16	9
2·5	0·32	37
2·5	0·64	89
2·5	1·28	100

TABLE XII.

PERCENTAGE MORTALITY (c = 0) OF *Tribolium confusum* ADULTS ALLOWED TO WALK ON DUSTS CONTAINING DIPHENYLAMINE WITH OR WITHOUT BENZYL ALCOHOL.

Diphenylamine, per cent.	In absence of benzyl alcohol.	In presence of 0·32 per cent benzyl alcohol.
0·625	17	32
1·25	22	19
2·5	22	37
5·0	42	34
10·0	56	31

These results show a marked rise in mortality as the concentration of penetrant rises, when the toxicant is kept at 2·5 per cent of the dust. When however, the penetrant is kept fixed at 0·32 per cent, altering the toxicant level makes no difference, although the mortality due to the toxicant alone rises with the toxicant level. It can also be seen that dusts containing the same ratio of diphenylamine to benzyl alcohol give different mortalities. Thus, although there are indications of penetrant action by benzyl alcohol in the case of this insect, the mechanism involved is obscure.

The results of a test with a fixed amount of parathion and varying proportions of benzyl alcohol are set out in Table XIII ; counts were made after $5\frac{1}{2}$ hours.

TABLE XIII.

PERCENTAGE MORTALITY OF *Tribolium confusum* ADULTS ALLOWED TO WALK ON DUSTS CONTAINING PARATHION AND/OR BENZYL ALCOHOL.

Parathion, per cent.	Benzyl alcohol, per cent.	Percentage mortality (c = o).
0·05	—	52·5
0·05	10	9·9
0·05	20	11·0
0·05	40	10·0
0·05	80	25·0
0·0	80	36·0

Here, again, the components appear to antagonize each other and reduce the kill due to either used alone.

In the spraying experiment, parathion was used at various concentrations, with and without 1 per cent benzyl alcohol, in a Tattersfield apparatus. Results are shown in Table XIV ; counts were made after 19 hours.

TABLE XIV.

PERCENTAGE MORTALITY (c = o) OF *Tribolium confusum* SPRAYED WITH EMULSIONS OF PARATHION WITH OR WITHOUT BENZYL ALCOHOL.

Parathion, per cent.	In absence of benzyl alcohol.	In presence of 1 per cent benzyl alcohol.
0·008	89	26
0·0066	75	84
0·0054	40	50
0·0045	12	28
0·0037	6	60
0·0030	1	28

The trend shown for mortality due to parathion alone is reasonably proportional to concentration ; but when benzyl alcohol is added, no such relation exists and there is no evidence of penetrant action except, perhaps, at the lowest concentrations of insecticide.

Summary.

The power of benzyl alcohol to facilitate penetration of diphenylamine shown by Webb and Green (1945) for the sheep ked, has been examined for eggs of a number of fruit pests and also for the adult insect, *Tribolium confusum* Duv. While the latter appears to react in a similar manner to the sheep ked, the eggs can be divided into two groups : (*a*) eggs into which penetration is facilitated, and (*b*) eggs into which penetration is not facilitated or is even reduced. The only egg falling in class (*a*) so far examined is the winter egg of the Fruit Tree Red Spider mite. The overwintering eggs of the Green Apple Aphis and the Winter Moth, and the summer eggs of the Fruit Tree Red Spider Mite fall into class (*b*).

In the case of winter eggs of the Fruit Tree Red Spider Mite, it has been found that benzyl alcohol will facilitate penetration of other ovicides, including azobenzene, azoxybenzene, *n*-dodecyl thiocyanate

and, to a lesser degree, bis(*p*-chlorphenyl) methyl carbinol (DMC). The low toxicity of diphenyl sulphone, a good summer ovicide for this pest, was not enhanced. It was also found that a number of compounds related to benzyl alcohol would act as penetrants, including β-phenylethyl alcohol, 3-phenylpropyl alcohol, *p*-tolyl carbinol, piperonyl alcohol, β-phenylethylamine and 2,4-xylen-1-ol. On the contrary α-phenylethylamine, butyl cellosolve and monoethanolamine reduced the toxicity of the ovicide used. Considerable variation in molecular structure may thus be possible without eliminating the penetrant action of benzyl alcohol.

Benzyl alcohol and *m*-cresol, appear to facilitate entry of acidic or weakly basic ovicides. Other compounds, such as methyl benzoate and benzylamine, seem more restricted in their penetrant action.

When *T. confusum* was employed as test insect, benzyl alcohol appeared to facilitate entry of diphenylamine, but not of parathion, dispersed on a celite dust. When applied by means of a spray, parathion by itself killed in proportion to concentration, but the addition of benzyl alcohol caused erratic results.

Benzyl alcohol was found to be harmless to *T. confusum* and also to the winter eggs of the Fruit Tree Red Spider Mite. The other eggs showed considerable susceptibility toward the higher concentrations of this substance. However, the antagonistic action shown in many of the experiments recorded above is not considered to depend on this factor.

References

Craufurd-Benson, H. J. and MacLeod, J. (1945-6). A.L.63, the original British army louse powder. *J. Hyg., Camb.*, **44**, 294-306.

Eaton, J. K. and Davies, R. G. (1950*a*). The insecticidal activity of some synthetic organo-phosphorus compounds. *Ann. appl. Biol.*, **37**, 92-104.

——— (1950*b*). The toxicity of certain synthetic organic compounds to the Fruit-Tree Red-Spider Mite. *Ann. appl. Biol.*, **37**, 471-89.

Wachs, H. (1947). Synergistic insecticides. *Science*, **105**, 530-1.

Webb, J. E. and Green, R. A. (1945). On the penetration of insecticides through the insect cuticle. *J. exp. Biol.*, **22**, 8-20.

HOPS

THE CLASSIFICATION OF HOP VARIETIES ACCORDING TO THEIR EASE OF PICKING

By F. H. BEARD

Introduction.

All hop growers are well aware that some varieties are much more easily, and therefore cheaply, picked than others. For example Fuggle is more easily picked than are the Goldings ; whilst amongst the new (Wye) varieties there are very great differences, Brewer's Favourite and Brewer's Gold probably representing the two extremes.

The relative ease with which a variety can be gathered is influenced by vigour and habit of growth, size of cones and the firmness of their attachment. None of these factors is alone responsible but the result depends on their interaction. For example, a variety making rather light bine growth and having shortish laterals bearing good-sized cones, easily detached, clear of small leaves, would be an ideal picker's hop ; whilst a variety making vigorous growth and having long, tangled laterals, bearing very small and firmly attached cones hidden amongst small leaves, would be very difficult to pick. In the past hops have been almost entirely picked by hand labour, but machine picking is now being used on a limited scale by some larger growers and is likely to become more general in the not so distant future. The characters mentioned above that make for easy picking by hand are not quite the same as those needed for satisfactory machine picking. This aspect will be referred to in greater detail later. Whilst the habit of growth and, to a lesser extent, the size of cone can be readily ascertained, the measurement of the amount of pull needed to detach the cones from the laterals presents more of a problem. Until definite information is obtained as to the amount of pull needed and the size of cones it is impossible to say how much these factors affect the ease of picking.

Towards the end of the 1945 hop season, Mr. I. H. Anstey, whilst on leave from The Canadian Army, became interested in the measurement of the force needed to detach cones and carried out some preliminary trials. Unfortunately, owing to the lateness in the season, the bulk of the East Malling hops had been picked but he found a significant difference between two groups of varieties. Anstey was able to develop a very satisfactory dynamometer, which was used under the direction of the writer in later seasons to obtain the data dealt with in this paper. The apparatus consists of a 50 lb. longitudinal spring scale with ratchet, from which the original spring is removed and replaced by a spring from a 1,000 gm. scale. The readings on the scale are therefore relative, but one unit equals approximately a pull of 20 gm. A simple hook was devised which could easily be slipped on the stalk of the cone. The stem was held and the scale pulled until the cone became detached from the lateral ; the reading was then taken before releasing the ratchet ready for the next cone.

In 1946 preliminary trials were made in collaboration with the Statistics Section to ascertain a suitable size of sample. It was found that two sample laterals taken from the upper portion of a single bine for each variety were adequate, except with varieties having very short laterals. With these varieties additional laterals were taken so that with every variety at least fifty cones were tested. All cones on the selected laterals were pulled and the test was carried out on each variety just prior to picking.

Amount of pull required for picking.

Data for eighteen varieties were obtained for the three seasons 1946-1948 and the mean values are presented in Table I. In the case of Petham Golding, Rodmersham Golding, Bramling, Early Bird and Mathon the results from season to season were not consistent but the data obtained shows clearly that the firmness of cone attachment is not of primary importance in deciding the picking qualities of a variety. Thus Early Promise, Fillpocket and Malling Midseason have firmly attached cones but are easy to pick owing to their good habit of growth, whereas Canterbury Golding requires the least pull of any variety but owing to its habit of growth it is troublesome to pick. Where easy detachment of cones is associated with a good habit of growth as in Brewer's Favourite, Fuggle, Concord, College Cluster and Quality Hop, the varieties are true " picker's hops ".

Size of cones.

Samples of cones were measured in two seasons, 1946 and 1948, the samples for 1947 being accidentally destroyed. There is, however, no evidence of any seasonal variation in the relative cone size of the varieties, though the general cone development was better in 1946 than in 1948. A generous sample of each variety was taken from the bulk of hops in the oast after they had been unloaded from the kilns. Dried cones were chosen in preference to green ones as the bulk of dried hops provides a more thoroughly mixed sample than green hops from the pickers' bins. Incidently it enabled the demand for recording labour to measure the cones to be spread over a longer and less busy period. From the sample collected in the oast fifty cones were taken at random and measured for length. A summary of these measurements is included in Table I. There is steady range from Petham Golding with a mean cone length of 2·5 cm. to College Cluster with a mean length of 3·7 cm. There is no indication that variations in cone size such as are shown in the Table have any marked effect on the ease of picking except where, as with Brewer's Gold and Canterbury Golding, small cone size is associated with poor habit of growth. It is interesting to note that the two extremes as regards ease of picking, Brewer's Gold and Brewer's Favourite, do not differ in cone size.

In considering the figures for size of cone two points must be borne in mind. The green, undried cones of all varieties will of course be larger than the dried ones. Also, cone development may be greatly influenced by environmental conditions such as soil, management, and pollination, thus Fuggle at East Malling does not have the good cone development found when the variety is grown in its real home, the Weald of Kent.

Classification of varieties according to the ease with which they can be picked.

The information obtained on the firmness of cone attachment and cone size, together with the writer's experience in supervising the picking of the varieties over a long period of years, indicates that habit of growth is the prime factor in determining the ease with which a variety can be picked, though the size of the cones and the firmness of their attachment do have a modifying effect. Table I summarizes these characters and lists the eighteen varieties according to the ease with which they can be picked.

In addition to these eighteen varieties, there are eight more recent introductions by Professor Salmon for which only one season's records on cone size and firmness of attachment are available. In view of the fact that ease of picking is primarily a matter of growth habit, an attempt to classify these varieties has been made in Table II, but the figures for cone size and particularly for firmness of cone attachment must be treated with reserve.

Requirements for machine picking.

The remarks in this paper refer to hand picking, but hop-picking machines are already in use by some of the larger growers and their use is likely to increase. It has not yet been possible to make actual tests with the various varieties, but reports from users of machines indicate the characters making for satisfactory machine picking, and they are not quite the same as for hand picking ; in particular, it is desirable that the petals do not part too readily from the strig or a broken and " chaffy " sample will result. Neither Fuggle nor the Goldings come out well in this test, the ripe cones of Fuggle especially being very liable to shatter even when picked by hand. This variety has large cones, but they are made up of loose and " puffed out " petals. Many of the new Wye varieties appear to be much more suitable for machine picking, having cones formed of a relatively large number of closely packed petals, and Brewer's Gold, which is the most difficult variety for hand picking, has been reported on favourably by at least one user of picking machines.

One of the new varieties, College Cluster, appears likely to be unsuitable for machine picking because the laterals break away very easily from the bine, so that the machine would probably tend to pull the laterals off the bine rather than the cones off the laterals.

Acknowledgements.

The author is greatly indebted to Mr. I. H. Anstey for his initial work in establishing a satisfactory technique for measuring the firmness of attachment of the cones. Miss D. J. Wilson carried out the pulling tests in 1946 and 1947, whilst in 1948 the author was assisted by Messrs. A. S. Nash (D.S.I.R., New Zealand) and P. J. Ormerod.

Summary.

The ease with which hops can be gathered is influenced by vigour and habit of growth, size of cone, and firmness of cone attachment, of which habit of growth is considered to be the most important

TABLE I.

SUMMARY OF CHARACTERS AFFECTING EASE OF PICKING OF VARIETIES FO

Variety.	General characters.	Mean pull to detach cones (1 unit = 20 gm.).
Brewer's Favourite (OP21)	Moderate vigour ; laterals medium-long but not intertwining ; cones borne clear of small leaves.	4·0
Concord (OH44)	Moderate vigour ; laterals medium ; no intertwining ; cones borne clear of small leaves.	11·8
College Cluster (N15 bis) ..	This variety has a very distinct habit, due to the limited growth of the bines, which barely reach the top of 13 foot wirework, but are closely packed with very fruitful laterals. At picking time the bines appear to be " all hops ".	11·8
Quality Hop (OO63) ..	Moderate-weak grower ; cones crowded on short upper laterals, but more separated on longer lower ones ; cones are borne clear of small leaves.	13·3
Fuggle	Vigour moderate-weak at East Malling, but on true " Fuggle land " can be vigorous ; laterals short to medium except where growth is vigorous when they are long ; cones borne clear of small leaves.	10·4
Early Promise (X35) ..	Moderate vigour ; lower laterals long, upper medium-short, no intertwining ; cones carried clear of small leaves.	21·2
Brewer's Stand-by (HH44)	Moderate vigour ; laterals long and often very straggling, but not intertwining ; cones borne clear of small leaves.	18·4
Malling Midseason (BB28)	Moderate vigour ; lower laterals long, upper medium ; tidy habit, forming compact but not " biney " heads.	17·4
Fillpocket (Z62)	Moderate vigour ; lower laterals long, upper short ; cones borne clear of small leaves.	21·4
Bullion (Q43)	Very similar in habit to Brewer's Gold (see below) but having firmer and bolder cones, which are rather less buried among the small leaves.	24·7
Mathon	Vigorous ; laterals long and intertwining, but cones less buried in the leaves than with other Goldings.	16·7
Bramling ..	Moderate vigour ; laterals long, with considerable intertwining when growth is strong.	12·2
Early Bird ..		13·0
Eastwell Golding	Vigorous ; intertwining, laterals long and with considerable " heads " formed.	16·6
Canterbury Golding		2·8
Rodmersham Golding		11·7
Petham Golding	Very vigorous.	11·6
Brewer's Gold (C9a) ..	The most vigorous variety ; laterals long ; lower laterals cross to adjacent strings and become secondary bines which often reach the top wire. These secondary bines give rise to a crop of cones closely borne on a twisted spiral and buried beneath the leaves of the main bine. Heads may be dense and have a proportion of soft, small "under hops". Cones tend to be feathery and soft.	17·1

WHICH COMPLETE RECORDS ARE AVAILABLE.

Mean length of dried cones, cm.	Picking grade.	Notes.
2·7	Very easy	A real "picker's hop"; the easiest to pick of any variety now grown.
3·0	Very easy	
3·7	Very easy	Laterals are very easily detached from bine and sub-laterals from main ones; hence hops may be picked somewhat "bunchy".
3·4	Very easy	
3·2	Very easy	Cones on "Fuggle land" larger than at East Malling.
3·4	Easy	
3·2	Easy	
2·9	Easy	
3·0	Easy	
3·2	Moderately easy to difficult	Ease of picking very dependent upon amount of bine growth. If bine growth is tangled owing to too close planting, too low wirework or training more than 1 bine per string, picking will be difficult.
3·0	Moderately easy	
2·7	Moderate	
2·7	Moderate	
3·1	Moderate to difficult	Ease of picking greatly influenced by amount of bine growth.
2·6		
2·7		
2·5	Moderate to difficult	
2·6	Difficult to very difficult	Ease of picking will vary according to how well excessive growth is controlled. If given ample room, with only 1 bine per string, picking is greatly facilitated. The most difficult variety to pick, but this is largely offset by the high quality of the hop and by the few bushels needed to yield 1 cwt. of dried hops.

actor. Information is given for Fuggle, seven Goldings and eighteen of the new varieties bred t Wye.

A technique is described for measuring the firmness of cone attachment.

Brief observations are made on the special requirements when picking is done by machine.

TABLE II.

SUMMARY OF CHARACTERS AFFECTING EASE OF PICKING OF NEWER VARIETIES (ONE SEASON'S PULLING TEST AND CONE MEASUREMENTS ONLY).

Variety.	General characters.	Mean pull to detach cones (1 unit = 20 gm.).	Mean length of dried cones, cm.	Picking grade.	Notes.
Keyworth's Early (OJ47)	Moderate vigour; upper laterals short with densely clustered cones, lower laterals medium; cones borne clear of small leaves.	13·2	3·4	Very easy	
Early Choice (FF21) ..	Moderate vigour; upper laterals medium-short with densely clustered cones; lower laterals medium-long, no intertwining; cones borne clear of small leaves.	8·4	2·7	Very easy	
Pride of Kent (170a) ..	Moderate vigour; upper laterals short, lower ones medium; cones borne clear of small leaves.	19·3	2·8	Easy	
Sunshine (V94)	Moderate vigour; upper laterals short with densely clustered cones; lower laterals medium; cones borne clear of small leaves.	15·1	2·9	Easy	
Keyworth's Midseason (OR55)	Vigorous; upper laterals medium with "bunchy" cones; lower laterals long with cones less densely clustered; no intertwining of laterals.	19·3	3·0	Easy	
Northern Brewer (WFA12)	Moderate vigour; upper laterals medium, lower laterals long; no intertwining of laterals.	23·2	3·3	Easy	Would be very easy to pick if cones were not so firmly attached.
John Ford (WFA90) ..	Moderate vigour; upper laterals long; lower laterals very long; no intertwining of laterals.	28·8	3·0	Easy	
Wye Field Golding (WFC81)	Moderate vigour; upper laterals long, lower laterals very long; no intertwining of laterals.	29·4	2·4	Easy	

PROPAGATION TRIALS WITH HOPS

VII. NUMBER AND SIZE OF SETS PRODUCED FROM STRAP-CUTS OF CERTAIN VARIETIES

By F. H. BEARD

Introduction.

In the course of routine propagation of hops over a number of years an impression was gained that varieties differed in the quantity and quality of the sets they produced and that the result was affected by the season. In an effort to obtain accurate data on these points the hop nursery from 1944-48 was planted with replicated, randomized plots of the main varieties. Some hop varieties are sensitive to the mosaic virus and cannot be grown alongside mosaic-tolerant varieties, which may act as symptomless carriers of this virus ; it was, therefore, necessary to have two trials widely separated from each other. As a consequence of this no comparisons can be made between the two groups of varieties.

The first trial, consisting of Fuggle and the principal new (Wye) varieties, all of which are mosaic-tolerant, was started in 1944. Each plot consisted of fifty strap-cuts of each variety and from 1944-6 there were ten replicates of each plot. After examination of the data over this period it was found possible to reduce the number of replicates to six and this was done in 1947 and 1948.

The second trial, of mosaic-sensitive hops, was not begun until 1945, when suitable material first became available. Twenty-five or thirty-two strap-cuts of each of seven clonal Golding selections were planted in from seven to ten replicated plots according to the amount of material available each season.

Varietal differences.

Percentage of good sets.

The results for both trials are presented in Tables I and II. In each case the mean percentage is given for each variety over the whole period, together with the order of placing in each year.

Mosaic-tolerant varieties.—Brewer's Favourite has consistently produced a low percentage of good sets with Fillpocket only slightly better. In an earlier report (Beard and Wilson, 1947), it was suggested that infection of the strap-cuts by Downy Mildew (*Pseudoperonospora humuli*) might be an important factor in determining the proportion of cuts that grow ; the present trial tends to confirm this for both Brewer's Favourite and Fillpocket strap-cuts are very subject to this disease. Brewer's Gold, which behaved irregularly in these experiments, is also subject, but its good performance in some

TABLE I.

PERCENTAGE OF GOOD SETS ; MOSAIC-TOLERANT VARIETIES.

Variety.	1944.	1945.	1946.	1947.	1948.	Mean percentage.
Fuggle (N clone)	I	H	H*	H	H	83·1
Brewer's Stand-by (HH44) ..	H	I	I	H	I	78·7
Quality Hop (OO63)	I	I	H	I	I	74·5
College Cluster (N15 bis)	H	I	I	L	H	72·9
Brewer's Gold (C9a)	L	H	I	I	I	72·8
Fillpocket (Z62)	I	L	L	I	L	65·4
Brewer's Favourite (OP21) ..	L	L	L	L	L	56·5

* Fuggle (G clone).

Brackets indicate non-significant differences (P = 0·05).

H denotes the two varieties giving the highest percentages of good sets, L the two giving the lowest, and I the three giving intermediate percentages, in each year.

seasons may be due either to less infection or to a more rapid development of the infection and of an obvious discoloration of the cuts that would lead to the majority of the infected cuts being rejected before planting. Of the varieties not affected by Mildew, Fuggle and Brewer's Stand-by produced significantly more sets than did Quality Hop or College Cluster.

Certain other varieties were included in the experiments in particular seasons and from the results obtained Bullion (Q43), Malling Midseason (BB28) and Early Promise (X35) fall in the middle group and Concord (OH44) approaches Fuggle in ease of propagation. Cuts from some one-year-old hills of Fuggle in 1944 produced just over 91 per cent of good sets, significantly more than from the established hills of Fuggle in that season. A strap-cut from a young hill has very close nodes and an abundance of buds towards its base, whereas a normal strap-cut usually has only two nodes with well-developed buds. The physiological condition of the cuts from the two sources may also be very different.

Mosaic-sensitive varieties.—Mathon has consistently produced a low percentage of rooted sets and Early Bird and Canterbury have not behaved much better. As with the mosaic-tolerant varieties, poor performance in this respect appears to be associated with Downy Mildew infection and these three varieties have all shown discoloured strap-cuts and even hills have been killed by the disease. Eastwell Golding and Bramling have shown less Mildew infection and have produced a higher proportion of good sets, while Petham and Rodmersham Goldings, which have given the best rooting, have been

TABLE II.

PERCENTAGE OF GOOD SETS ; MOSAIC-SENSITIVE VARIETIES.

Variety.	1945.	1946.	1947.	1948.	Mean percentage.
Petham Golding	H	H	H	H	83·6
Rodmersham Golding	H	H	H	H	81·4
Bramling	I	I	I	I	76·2
Eastwell Golding	I	I	I	I	74·4
Canterbury Golding	I	I	L	I	62·4
Early Bird	L	L	I	L	54·3
Mathon	L	L	L	L	49·0

Brackets indicate non-significant differences (P=0·05).

H denotes the two varieties giving the highest percentages of good sets, L the two giving the lowest, and I the three giving intermediate percentages, in each year.

quite free from this form of Downy Mildew attack. The big difference in behaviour between Early Bird and Bramling is surprising as Early Bird originated as a selection from Bramling in the late nineteenth century. It is doubtful if there is any real difference in the ability to produce good sets apart from the effect of this susceptibility to Downy Mildew.

Size of sets.

In each season the lifted sets were shaken free of soil and weighed. In estimating size in this way there is a bias in favour of the smaller set because proportionately more of the roots of the large set is left in the ground. There is also a bias in favour of those varieties with a low percentage of good sets because the wider the sets are apart, the larger they are (Beard, 1947). The results are presented in Tables III and IV in a similar manner to that in Tables I and II.

TABLE III.

WEIGHT OF SETS ; MOSAIC-TOLERANT VARIETIES.

Variety.	1944.	1945.	1946.	1947.	1948.	Mean weight (lb.) of 100 sets.
Quality Hop (OO63)	H	I	H	H	H	19·9
Fillpocket (Z62)	H	H	H	I	I	19·3
College Cluster (N15 bis)	I	H	I	H	H	18·9
Fuggle (N clone)	I	I	I*	I	I	18·0
Brewer's Favourite (OP21) ..	I	I	I	I	I	17·1
Brewer's Gold (C9a)	L	L	L	L	L	17·0
Brewer's Stand-by (HH44) ..	L	L	L	L	L	13·6

* Fuggle (G clone).

Brackets indicate non-significant differences (P = 0·05).

H denotes the two varieties giving the heaviest sets, L the two giving the lightest, and I the three giving sets of intermediate mean weight, in each year.

TABLE IV.

WEIGHT OF SETS ; MOSAIC-SENSITIVE VARIETIES.

Variety.	1945.	1946.	1947.	1948.	Mean weight (lb.) of 100 sets.
Rodmersham Golding	H	H	I	H	26·4
Petham Golding	H	H	I	H	25·9
Mathon	I	I	H	I	24·6
Canterbury Golding	I	I	H	I	24·3
Early Bird	L	I	I	I	21·6
Eastwell Golding	L	L	L	L	21·1
Bramling	I	L	L	L	20·3

Brackets indicate non-significant differences (P = 0·05).
H denotes the two varieties giving the heaviest sets, L the two giving the lightest, and I the three giving sets of intermediate mean weight, in each year.

Mosaic-tolerant varieties.—The smallest sets have been produced by Brewer's Stand-by, which it will be remembered, gave a high proportion of good sets. Fuggle, though also giving a good take, produced sets of medium size. Fillpocket produced larger sets than Brewer's Favourite, although they both produce relatively few sets. Of the varieties for which less complete data are available, Malling Midseason and Concord produced large sets, Early Promise medium sets and Bullion small sets.

Mosaic-sensitive varieties.—Petham and Rodmersham Goldings have produced the largest sets although they also produced the greatest number. In spite of wide differences in the numbers of sets produced by Early Bird and Bramling, there is little difference between the size of the sets.

Seasonal differences.

No clear seasonal influence was observed in the number of sets rooting except that the rooting of all the mosaic sensitive varieties was low in 1947, doubtless because of the very late planting of the cuts. A pronounced effect was observed on size of set, the seasons 1945 and 1947 being particularly poor in this respect and 1948 particularly good. An examination of the monthly and weekly rainfall and sunshine records failed to provide an explanation.

Summary.

Propagation trials of strap-cuts of seven mosaic-tolerant and seven mosaic-sensitive hops showed varietal differences in the number and size of good sets produced. In most cases differences in the number of sets produced could be associated with the incidence of Downy Mildew (*Pseudoperonospora humuli*) in the cuts. Differences in size were not always linked with the percentage rooting. It was not possible to correlate weather conditions with the seasons when large sets were produced.

REFERENCES

BEARD, F. H. (1947). Propagation trials with hops. VI. The effect of spacing cuttings (strap-cuts) in the nursery rows on the number and size of set produced. *Rep. E. Malling Res. Sta. for 1946*, 140-1.

——— and WILSON, D. J. (1947). Propagation trials with hops. V. Further experiments in treating cuttings (strap-cuts) with growth substances. *Rep. E. Malling Res. Sta. for 1946*, 136-9.

Part IV

BULLETINS FOR FRUITGROWERS

RESEARCH ON FRUIT TREE ROOTSTOCKS*

By T. N. HOBLYN

Introduction.

From the earliest days of the East Malling Research Station the " *build-up* " of the fruit tree has been the central theme around which the research has been organized.

The normal deciduous fruit tree consists of two parts, the rootstock, which forms the root system and a small part of the stem, mostly below ground level, and the scion, which forms the main trunk, crotch and branches of the tree. In particular localities, for certain plum varieties, e.g. Pershore Yellow Egg or Cambridge Gage, the whole tree is formed of a single variety on its own roots, but sometimes a more complex tree is needed and an intermediate is added between rootstock and scion, either to overcome incompatibility or to increase resistance to disease, e.g. Bacterial Canker of plums (*Pseudomonas mors-prunorum*), or, in some countries, winter injury. The amount of such an intermediate may vary from a few inches to the whole trunk and crotch of the tree.

In 1913, although the more important scion varieties, with the possible exception of cherries, were readily obtainable true to name, there was very little reliable information about the rootstocks upon which they were worked. Tradition averred that, in general, apple, pear, Myrobalan plum and Mazzard cherry rootstocks, raised from seed, gave deep rooted, vigorous, long-lived trees ; on the other hand, the " Paradise " apple, the quince and certain varieties of plum, which could be readily obtained from layers or cuttings, were supposed to produce more shallow rooting, smaller, quick cropping apple, pear and plum trees. There was no dwarfing rootstock for cherries.

The orchards of England, at the time, showed clearly that these assumptions needed investigation and the range and potentialities of fruit tree rootstocks was, therefore, one of the first subjects for investigation by the original small research team at East Malling. Their primary object was the establishment of standardized fruit trees whose future behaviour could be forecast, both for the fruit-grower and as a firm basis for the scientific investigation of further fruit-growing problems.

The characteristics of a good rootstock.

The tree raiser demands, firstly, a rootstock that can be readily and cheaply obtained. It should be resistant to diseases and pests, e.g. Crown Gall (*Bacterium tumefaciens*) and Woolly Aphid (*Eriosoma lanigerum*), and compatible with the scion varieties to be budded or grafted upon it, so that most of the trees produced are saleable : a straight, clean stock stem free from spines, the bark of which runs easily when the bud is inserted, is also important.

The growers' main concern is the production of uniform high-cropping trees of predictable performance showing no signs of delayed incompatibility, so that their orchards can be planned and managed economically without undue losses. In England, fruit trees are required which range from single cordons, normally planted at about 2,000 trees to the acre, to standard trees on six foot stems at forty feet apart in permanent grass, grazed by stock or kept short by mowing. While the right selection of scion varieties for each particular purpose is important, the choice of an unsuitable rootstock may be fatal. Apart from this, the root system must have good anchorage, to minimize the need for staking ; it should not itself be susceptible to diseases or pests or communicate such susceptibility to the scion variety, nor should its nutritional requirements be exceptional. In particular countries or on certain soils, resistance to winter cold or drought is essential.

Seedling rootstocks.

The most common rootstocks grown from seed and formerly used in this country were the " Crab " or " Free " apple, the " Free " pear, Myrobalan, St. Julien and Black Damas plums and the Mazzard cherry. The seed for plums and cherries was collected sometimes from wildings in their

* Reprinted by permission from British Agricultural Bulletin.

native habitats and this quality was also supposed to distinguish the " Crab " from the " Free " apple rootstock. Sometimes the seed was obtained from a single named variety, admittedly open pollinated, but said to produce comparatively uniform seedlings ; more often, however, the source was a heterogeneous collection of cider or perry fruits, the seed being extracted from the pomace. Hatton (3) examined very carefully the evidence concerning the use of seedling rootstocks and came to the conclusion that, at any rate under English conditions, whatever the source of the seed, the resulting rootstocks themselves and the trees worked upon them were extremely variable, not only in their growth and cropping, but in many other characteristics as well. Of these, variations in rootstock/scion compatibility were the most important.

Attempts have been made at various times to improve the uniformity of trees on seedling rootstocks, notably in Germany (7) and the United States (18). The elimination of triploid varieties as seed parents has been shown to effect an improvement (5) and for this reason the processing plants of the Pacific Northwestern area of the United States were recommended as suitable sources of seed for apple rootstocks, since the triploid variety Baldwin is not grown there. Nevertheless, research has shown that, even among diploid varieties, the selection of suitable mother varieties is important, and recently doubt has been cast on the wisdom of using these " by-products plants " as a seed source, since the main varieties grown there, Delicious and Winesap, produce inferior seedlings (12). The most promising variety as a source of seed is Jonathan (18).

The practice of bench-grafting the scion on to a piece of one-year-old seedling root has also been claimed to produce uniform trees, either because the seedling acts as a " nurse-root ", the scion rapidly establishing itself on its own roots, or because the seedling root takes on the root character of the scion (13).

As long as only one type of tree is required and seed is readily available, one or other of these methods may eventually prove successful, especially where two- or three-year-old trees are planted and the weaklings eliminated in the nursery. Nevertheless, it must be remembered that variation lies not in the size of tree alone and trees that are uniform in size may still vary in amount and regularity of bearing, time of blossoming, size and quality of fruit, resistance to disease or frost injury and nutritional requirements, all of which are just as important.

In England, modern methods of crushing have rendered cider apple or perry pear pomace an unlikely future source of seed, while the only apple used for processing in any quantity, Bramley's Seedling, is a triploid and, therefore, useless. In the United States the large Bartlett pear canning industry is a convenient seed source, but there is no comparable industry in England.

For these reasons most of the research here has been concentrated upon the production of vegetatively raised rootstocks ; these possess many advantages and are likely to be mainly used for many years to come.

Vegetatively raised rootstocks.

The history of the collection, botanical description, classification, propagation and trial at East Malling of re-selected or new clonal races of the rootstocks found in commerce, has been described in a series of papers by Hatton and his colleagues. It is not proposed to cite these papers in detail here, but the student should consult the Reports of the Station, the Journal of Pomology and Horticultural Science and the Journal of the Royal Horticultural Society, wherein most of these reports may be found. Some apple, plum and quince rootstocks had been raised vegetatively for many years, but they were often mixed or misnamed and reselection was necessary before they could be tried with confidence ; the Doucin (M.II) apple, Brompton plum and Angers (A) quince are examples. In other instances, new clonal races were raised from individuals showing promise of ready rooting selected from samples of seedlings in commercial use. The Malling selected " Crab C " apple, Myrobalan B plum and F12/1 cherry are examples. Hatton summarized his twenty-five years experience with these rootstocks in a brief survey in 1939 (4).

During the decade that has elapsed since then, the trials of rootstocks at East Malling have reached maturity. Since 1940, also, accounts of trials at various Stations in each of twelve different countries have appeared—Australia, Canada, Czechoslovakia, Finland, Germany, Holland, India, Kenya, New Zealand, Sweden, Switzerland and the United States. Not all these reports are entirely favourable and, as might be expected, rootstocks that are of value in England are not always suited to other climates and vice versa ; but the principle of the selection and multiplication of clonal stocks suited to each particular locality is generally accepted, not only for deciduous fruits, but for many tropical and sub-tropical trees as well. For the time being, in some parts of the World, seedling rootstocks are still most widely used and, although the desirability of clones for particular purposes is agreed, until the methods of propagation can be mechanized and thus cheapened they are unlikely to

be widely adopted. In England, however, except where research has not yet found a readily propagated substitute for the seedling, vegetatively raised rootstocks are now the mainstay of the fruit-growing industry.

The propagation of vegetatively raised rootstocks.

Methods of propagation can be divided into two main classes, stooling and layering, where the progeny remain attached to the parent plants until they possess both roots and shoots, and cuttings, where pieces of shoot or root are first removed from the parent plant (9). The former are the more important and were studied particularly in the early years. Apples and quinces were mainly grown by the easier stooling method and plums and cherries by layering. One of the more important research contributions was the discovery that if the young shoot grows through a layer of soil, before reaching the light, so that the basal portion is etiolated, certain varieties, particularly of plum and cherry, which otherwise do not respond to the layering method, can be induced to root readily (8).

These methods which have been described in detail by Garner (1), are now more or less standardized. The production of one-year-old layered rootstocks fit for budding varies from 20,000 to 70,000 per acre, according to variety, with about two-thirds as many again of a smaller or poorly rooted grade, which can be planted out and will in a normal year produce many useful " bedded stocks ". Nevertheless, the processes of stooling and layering involve much hand labour and attention in recent years has been directed towards means of performing some of the operations mechanically.

Certain plum rootstocks such as Myrobalan B and Marianna are commonly produced comparatively cheaply from hardwood stem cuttings. The sources, planting distances and treatment of stem cuttings have been carefully studied and for these varieties this is now a standard method (1, 9). Efforts to improve the rooting of stem cuttings of the more shy rooting sorts are continuing. The use of synthetic growth substances such as α-naphthalene-acetic acid or β-idolyl-butyric acid has effected some slight improvement, but the source of the cutting itself has proved much more important. Thus cuttings taken from an established hedge have been much more successful than from vigorous plants widely spaced in the nursery. A recently constructed island at East Malling with terraces at varying heights above the water table, together with facilities for overhead irrigation, will provide an excellent site for further intensive research on this method of raising rootstocks.

Root cuttings from two- or three-year-old trees provide an alternative method, which has proved particularly useful for propagating a desirable vigorous rootstock for apples, Crab C, which must otherwise have been discarded. The method presents the most promising chance of propagating on a large-scale the clonal selections from the " Free " pears. Although some of these have proved promising vigorous rootstocks they have never reached commerce, since once the " juvenile " stage of the original seedling parents had been passed, they consistently failed to root by ordinary layering methods.

The position in 1950.

Apples.

The field trials of the older Malling rootstocks have now been in progress for over thirty years. Their growth and cropping during the earlier years is well known (3), but the performance during the last ten years, when the trees may be considered mature, has not so far been reported on. Of the original seventeen so-called " Paradise " rootstocks, only seven can now be considered of general interest. This does not mean that the remainder may not be useful in other countries and, indeed, one or two, which show special qualities or defects, are in demand for research purposes. Broadly these rootstocks still fall into four main groups (see Fig. 2) :—(i) Dwarfing—represented by M.IX, (ii) semi-dwarfing—M.VII, (iii) Vigorous—M.I. and M.II and (iv) Very vigorous—M.XVI and M.XII. Between groups (ii) and (iii) should be added M.IV, which despite poor nursery performance and anchorage, has been retained because of its heavy cropping qualities. In the early years, it may be remembered, it was in the very vigorous class.

In Table I are shown the size and average annual cropping over the last ten years of Lane's Prince Albert, Bramley's Seedling and Worcester Pearmain on these rootstocks. Only the combination of Bramley on M.IX is missing, since these trees became scion rooted in their early years. The size of the trees is represented by the area of the cross section of the trunk in sq. cm. at thirty-years-old and the average spread in metres of the branches at twenty-four-years-old. The latter dimension, indicative of the space taken up by the tree, was sometimes restricted by the distance of planting. The cropping potentialities of these mature trees are indicated by the average annual crops in pounds per tree during the last ten years.

Table I.

Size of thirty-year-old bush apple trees and cropping from 21st to 30th years of three varieties on different rootstocks.

On rootstock.	Lane's Prince Albert.			Bramley's Seedling.			Worcester Pearmain.		
	Cross section, sq. cm.	Spread, m.	Average crop per year, lb.	Cross section, sq. cm.	Spread, m.	Average crop per year, lb.	Cross section, sq. cm.	Spread, m.	Average crop per year, lb.
IX (i)	74	2·7	44	—	—	—	111	3·4	76
VII (ii)	185	4·1	81	646	7·4	333	209	4·2	119
IV	278	4·7	135	865	8·5	448	283	4·8	184
I (iii)	361	5·3	155	998	8·2	403	314	4·9	165
II (iii)	341	5·2	146	1,138	9·1	497	331	5·0	195
XVI (iv)	446	6·2	191	894	8·7	364	542	5·9	239
XII (iv)	510	6·2	151	1,257	9·4	391	555	6·1	199

Broadly the four groups are distinct in size of tree. Within group (iii) the relative performance of M.I and M.II varies with the variety ; thus with Bramley's Seedling (and Cox's Orange Pippin) trees on M.II are much the larger, but there is very little difference with Lane's Prince Albert and Worcester Pearmain. In trials outside East Malling the relative performance of these two rootstocks also varies with the soil. Trees on M.I have proved very susceptible to drought, although they have done well in heavy moisture-retaining soils and under irrigation ; for this reason M.II is now often preferred and is the most popular rootstock for permanent bush trees. Although Bramley's Seedling on M.II has actually made a larger tree than on M.XVI—a finding that needs confirmation since the number of trees is now small—M.XVI and M.XII generally form a group of their own, with the latter as a rule rather larger. The slowness of trees on M.XII to come into bearing and its rather poor propagation qualities have caused it to lose favour even for very vigorous trees and M.XVI answers most of the growers' needs for large trees. None of these trees, at present, shows any definite signs of a falling off in vigour or cropping. The yield when mature has been generally in proportion to their size, with the exception of heavy cropping M.IV and poor cropping M.XII. Other differences in tree characters influenced by rootstock reported by Hatton (3) earlier have persisted, while others, e.g. response to mineral deficiency, have appeared since.

One or two of the older rootstocks are also worth mention. As an alternative very vigorous rootstock, Crab C, now that a means of propagation has been found, has recently come to the fore. At the time that East Malling was collecting and examining the " Paradise " stocks, similar work on the " Free " stocks was in progress at Long Ashton Research Station, where a series of clonal apple stocks was also raised (11, 6). Few of these appeared superior to those described above, but two, Long Ashton F.11 and E.8, have been retained for further trial as semi-dwarfing rootstocks. The Merton rootstocks resistant to Woolly Aphid Nos. 778, 779, 789, 793 (15), though not distributed in England, have by reason of this character found favour abroad, particularly in Australia (14). Their vigour is similar to that of M.II.

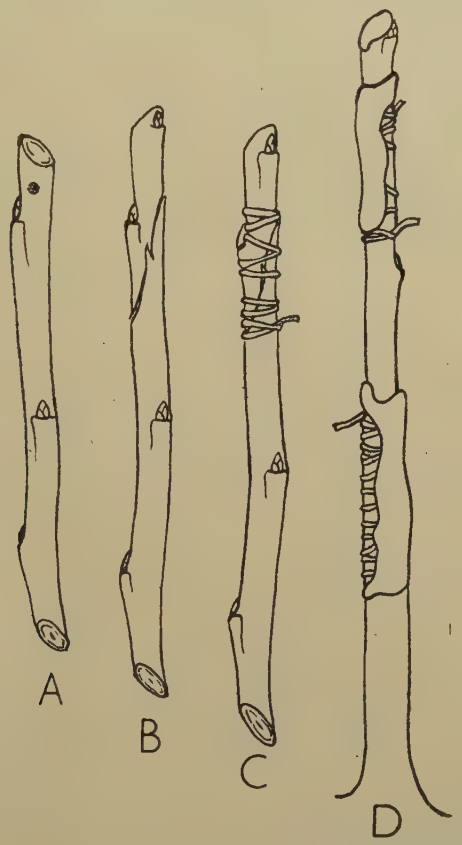
These then are the apple rootstocks now in commerce, of which M.IX, M.VII, M.II, and M.XVI are most used. Even these four could well be improved upon ; a rather more sturdy dwarfing rootstock than M.IX would be an asset ; M.VII is particularly liable to the Crown Gall (*Bacterium tumefaciens*) disease, while the galls produced as a result of infestations of Woolly Aphid (*Eriosoma lanigerum*) on M.XVI are a serious drawback to tree raisers. Twenty-six years ago breeding work was started to fill some of the gaps. One series, supplementary to the Merton rootstocks alluded to above aimed at the production of a new series of rootstocks with the qualities of the standard ones and an added resistance to Woolly Aphid. They were bred by crossing the immune Northern Spy with all the original Malling stocks. The long process of breeding, selecting and testing some 2,300 seedlings from these crosses (16), first in the nursery and then in the field, is now approaching fruition and a very few selections are being propagated in quantity with a view to their distribution to the nursery trade. A second series, not so advanced, may provide a semi-dwarfing rootstock to replace M.VII and M.IV. This series did not aim at Woolly Aphid resistance, but all seedlings had M.IX as one parent. Considering this fact, the range of vigour is remarkable—from rootstocks even more dwarfing than M.IX, now

being used for special experimental purposes, to a rootstock likely to be more vigorous than M.XVI and M.XII. If this last proves also heavy cropping and a good nursery stock it may be a valuable acquisition.

Pears.

The provision of a range of rootstocks for pears has been complicated by incompatibility and the difficulty of propagating vegetatively selections from " Free " or seedling pears.

In England a moderate sized pear tree is most required, and for this the Angers, Quince A, rootstock and Common Quince B, which closely resembles it in performance, suit most varieties. But a few pears, e.g. Williams' Bon Chrétien (Bartlett), are more or less incompatible with all quince rootstocks now grown in England and must be double-worked to produce reliable trees. An inexpensive method in one grafting operation in the nursery has been described by Garner (1) (see Fig. 3). A third



(Drawing by R. J. Garner.)

FIG. 3.

Double-working pear on quince in one operation :
A. A length of intermediate.
B. A short scion of the variety to be propagated grafted to the intermediate.
C. Tied and ready for sealing.
D. The complete scion grafted to the established quince rootstock in the nursery.

variety, Quince C, is more dwarfing and quicker cropping than the other two, but is less well anchored, while trees on it are apt to suffer from a disorder known as " Bark Blister ", especially in the early years. It is most used for slow cropping varieties and garden trees. If the union of a vigorous pear variety on quince is buried below ground, scion rooting is apt to occur. This often results in ultra vigorous and, unlike apples, very poor yielding trees of no commercial value (see Fig. 4).

The relative size and cropping of thirty-year-old Conference on Quinces A and C are shown in Table II. It will be noted that the range is smaller than that between M.IX and M.VII apple rootstocks (see Fig. 5).

TABLE II.

SIZE AND CROPPING OF THIRTY-YEAR-OLD TREES OF CONFERENCE PEAR ON QUINCES A AND C.

On.	Area of cross section of stem, sq. cm.	Average annual crop 21st to 30th year, lb.
Quince A	220	90
Quince C	153	70

More generally compatible quince rootstocks are still being sought. Many clones raised from seedling quinces from the Caucasus yielded no rootstock of promise in this respect. Recently, attention has been focused on quinces from France and Germany, particularly the so-called Quince de Provence (17), said to grow wild in the hedgerows and to be compatible with Williams' and other " difficult " pears. Actually this variety apparently includes several nurserymen's selections propagated vegetatively. Whether any of these has the desired quality has yet to be proved.

Although the Malling " Free " pear selections tend to give greater vigour than quince, they are not all vigorous and among them were found several that were incompatible with Dr. Jules Guyot worked on them (3). Again, there is not the same range as in apples. Table III gives the size and cropping of twenty-five-year-old Dr. Jules Guyot on three selections.

TABLE III.

SIZE AND CROPPING OF TWENTY-FIVE-YEAR-OLD HALF-STANDARD DR. JULES GUYOT PEAR ON CLONAL " FREE " PEAR SELECTIONS.

On.	Area of cross section of stem, sq. cm.	Average annual crop, lb.	
		11th to 20th years.	21st to 25th years.
C.1	309	48	134
C.6	217	38	99
C.8	120	18	42

It may be noted that Pear C.8, which gave most promise as a semi-dwarfing stock, did not show any sign of precocity but has cropped very much according to its size. A new series of pear rootstocks is now under trial.

Plums.

Very few of the plum rootstocks in the original Malling trials are now being propagated commercially. As in pears, uncertain compatibility and poor nursery performance are mainly responsible ; but other factors, such as a propensity for suckering, have helped towards the disappearance of such rootstocks as Brussels, at one time esteemed for Victoria plums of medium vigour. Even Myrobalan B, the East Malling selection from the seedlings of commerce, in other respects an excellent rootstock, is incompatible with a few gage plums and with peaches. No case of incompatibility with plums has yet been found in trees on Brompton, Pershore and Common Mussel, but all three have other faults.

Table IV shows the size and cropping of twenty-five-year-old Rivers' Early Prolific plum on the main commercial rootstocks. Fig. 6 illustrates Victoria on Myrobalan B and Common Plum at thirteen years old. Of these Pershore, mostly from orchard suckers and by no means always true to name, is still used in the West Country, but cannot be propagated readily from layers or cuttings. Common Mussel also is now only used where a compatible semi-dwarfing rootstock is not available. It suckers badly and it suffers readily from mineral deficiencies. Common Plum and Marianna are valuable, but only for plums with which they are compatible, the first as a semi-dwarfing rootstock, which also encourages trees worked upon it to recover from Silver Leaf disease, and the second for heavy cropping. Brompton is expensive to propagate and is more often used for the more valuable peach tree. Plums on Brompton have not been as vigorous as was at first anticipated, but the rather poor cropping of Rivers' upon it is not characteristic of all varieties. Myrobalan B has always been outstanding for

Fig. 1.
General view of stool and layer beds at East Malling, July, 1950.

[face p. 198

FIG. 2.
Thirty-two-year-old Worcester Pearmain apple on "A"—M.IX; "B"—M.VII; "C"—M.II; and "D"—M.XVI.

FIG. 4.
Doyenné du Comice on Quince, not scion rooted (left), and scion rooted (right).

FIG. 5.
Thirty-two-year-old Conference pear on Quince A (left), and on Quince C (right).

FIG. 6.
Thirteen-year-old Victoria plum on Myrobalan B (left), and on Common Plum (right).

TABLE IV.

SIZE AND CROPPING OF HALF-STANDARD RIVERS' EARLY PROLIFIC PLUM ON DIFFERENT ROOTSTOCKS.

On.	Cross section of stem in sq. cm.	Height in m.	Spread in m.	Average annual crop 16th to 25th years, lb.
Pershore	187	5·1	5·5	70
Common Plum ..	201	5·1	5·5	71
Common Mussel ..	222	5·6	5·6	76
Brompton	247	5·6	5·8	68
Marianna	250	4·9	5·9	84
Myrobalan B ..	314	6·1	5·9	96

vigour and crop, it propagates readily from cuttings and has the merit of being itself highly resistant to Bacterial Canker (*Pseudomonas mors-prunorum*). For this reason, it is now recommended as a stem-builder on its own roots for susceptible varieties (10). Of other established rootstocks peculiar to certain localities, only Warwickshire Drooper need be mentioned as an alternative stembuilder resistant to Bacterial Canker.

Some of the selected clonal St. Juliens are now coming forward as possible rootstocks for smaller trees and one of these, St. Julien A, and a more vigorous selection, Damas C, have proved widely compatible with plums and peaches. Others are under trial. For the future an extensive search of plum-growing areas in England and in France has been made for a possible source of dwarfing or semi-dwarfing plum rootstocks and, in this, new knowledge of the histology of rootstocks of varying vigour is being used to forecast their possibilities.

Cherries.

Attempts have been made to provide vegetatively raised cherry rootstocks from three species, *Prunus avium*, the sweet cherry or Mazzard, *P. mahaleb* and *P. cerasus*, the acid cherry (2). Of these only one, a selected Mazzard F12/1, is now found in commerce in England. This is a most valuable rootstock for large cherry trees and is resistant to Bacterial Canker and so suitable for high-working susceptible varieties. Twenty-three-year-old trees of Early Rivers cherry on this rootstock seem likely to fill the ground easily at forty feet apart and are now cropping at an annual rate of about 170 pounds per tree.

Although no difficulty was found in propagating sweet cherries vegetatively and there has been no evidence of incompatibility, there was not the range of vigour among the *P. avium* rootstocks that was found in apples, and none giving appreciable dwarfing was found among the selections tried. *P. mahaleb* selections gave quick-growing trees of Morello (2), but these were short-lived and are not now recommended. For sweet cherries, their main merit seems to be ease of roguing in the nursery, since it is difficult to pick out bud failures on Mazzard stocks owing to the close similarity of the foliage with that of the scions.

Research is proceeding among the acid cherries for a less vigorous rootstock, compatible with sweet varieties, to provide the quick-cropping bush cherry tree that the exigencies of modern fruit growing demand. So far no suitable rootstock has been found.

In this brief review it has only been possible to sketch lightly the merits and demerits of the rootstocks now in commerce and indicate in what direction improvements may be expected, though many of these still lie well ahead. It has not been possible to describe at all the extensive research on the mechanism of rootstock effect, the causes of incompatibility and the reasons for host resistance to disease, which is still in progress. Further light on these problems will materially aid the production of new and better rootstocks, either by selection from natural sources or by breeding. Much of this work will take many years to mature, but in the meantime it can be said that to-day the English fruitgrower can buy trees on rootstocks certified true to name by the Ministry of Agriculture, the potentialities of which are well known, and can plan and manage his orchards accordingly.

Summary.

A broad review of research on rootstocks over the past thirty-eight years, indicating the lines along which there is likely to be progress in the future.

References

(1) Garner, R. J. (1947). The Grafter's Handbook. Faber & Faber, London.
(2) Grubb, N. H. (1949). Cherries. Crosby Lockwood & Son Ltd., London.
(3) Hatton, R. G. (1930). The relationship between scion and rootstock with special reference to the tree fruits. *J. Roy. hort. Soc.*, **55**, 169-211.
(4) ——— (1939). Rootstock work at East Malling. *Scientific Horticulture*, **7**, 7-16.
(5) Hewetson, F. N. (1941). The effect of diploid and triploid seedling stock on the growth and yield of certain Jonathan apple trees. *Proc. Amer. Soc. hort. Sci.*, **38**, 341-4.
(6) Hoblyn, T. N. (1940). Trials of clonal apple rootstocks selected from " Free " and " Crab " seedlings. II. Performance at East Malling when worked with Lane's Prince Albert. *J. Pomol.*, **18**, 239-48.
(7) Kemmer, E. and Schultz, F. (1939). Die beteutung des sämlings als unterlage. *Landw. Jb.*, **89**, 114-39.
(8) Knight, R. C., Amos, J., Hatton, R. G. and Witt, A. W. (1928). The vegetative propagation of fruit tree rootstocks. *Rep. E. Malling Res. Sta. for 1926-7, II Suppl.*, 11-30.
(9) Ministry of Agriculture (1949). Fruit Tree Raising. Ministry of Agriculture and Fisheries, London, Bull. **135**, published by H.M. Stationery Office.
(10) Montgomery, H. B. S., Moore, M. H. and Hoblyn, T. N. (1943). A field trial of measures designed for the control of Bacterial Canker of Victoria plum trees. *Rep. E. Malling Res. Sta. for 1942*, 53-61.
(11) Spinks, G. T. (1940). Trials of clonal apple rootstocks selected from " Free " and " Crab " seedlings. I. Performance at Long Ashton when worked with five scion varieties. *J. Pomol.*, **18**, 226-38.
(12) Sudds, R. H. (1949). Sixteen years' results of orchard tests with trees on selected rootstocks. Kearneysville, W. Va. *Proc. Amer. Soc. hort. Sci.*, **54**, 144-8.
(13) Swarbrick, T. and Roberts, R. H. (1927). The relation of scion variety to character of root growth in apple trees. Univ. of Wisconsin Agric. Expt. Station Res. Bull., **78**.
(14) Thomas, L. A. (1945). Stock and scion investigations. V. A nursery trial with apple rootstocks. *J. Coun. sci. industr. Res. Aust.*, **18**, 349-54.
(15) Tydeman, H. M. (1940). Apple rootstocks immune from woolly aphis. III. The influence of four new seedling immunes on Lane's Prince Albert. *Rep. E. Malling Res. Sta. for 1939*, 46-8.
(16) ——— (1946). A progress report on breeding work with the tree fruits. *Rep. E. Malling Res. Sta. for 1945*, 63-6.
(17) ——— (1948). Descriptions of some quince rootstocks. *Rep. E. Malling Res. Sta. for 1947*, 59-64.
(18) Yerkes, G. F. and Sudds, R. H. (1939). Influence of ten stocks on the performance of certain apple varieties. *Proc. Amer. Soc. hort. Sci.*, **36**, 116-20.

MECHANICAL AIDS TO NURSERY WORK

By F. H. VILLIERS and T. V. DIXON

With the rapid increase in labour costs after the war it became obvious that something drastic would have to be done to reduce the amount of hand labour used in the experimental nursery at the Research Station. Two very successful mechanical aids, which may be of interest to other nurserymen and growers, have been evolved.

Whilst visiting the Continent in 1945, Mr. R. J. Garner was very impressed with the work accomplished by a tree lifting plough, which he saw in use in North-West Germany, and he obtained permission to import one for trial in this country (Fig. 1). This implement was tried in its standard form on rows of bedded rootstocks but the sandy loam soil at East Malling is apparently very much heavier than that in which the plough was designed to work. It was found that two heavy horses could not pull the plough satisfactorily and that it was very difficult to handle. Enough was done; however, to show the great possibilities of such an implement ; the rootstocks were completely loosened in the soil and could be pulled up easily by hand with almost the whole root system intact.

During the next two seasons the German plough was used to lift all bedded rootstocks but it was pulled by a tractor which straddled the rows. This was a great saving of labour, though the plough still had to be guided by hand, but the most serious disadvantage was that some of the stocks were damaged by the passage of the tractor and by scraping along under the plough beam. It was decided, therefore, to make a lifting device, similar in essentials, which could be offset from the tractor so that all damage would be avoided and with which maiden trees and bush fruits could also be lifted.

The final result was a modified Ransome cultivator (Figs. 2 and 3) which has been in use throughout the 1950-51 season with excellent results. Only one man, the tractor driver, is needed to operate the implement ; the stocks and trees are loosened to such an extent that they can be pulled up by hand quite easily, while they retain much more root than is usually obtained when lifting with spades. Trees as large as two-year-old plum trees have been successfully lifted.

The share and supporting arm are standard components of a " Blackstone " potato lifter, about 5 inches was cut off the outside end of the share and the three lifting prongs of 1 inch square mild steel welded to the back. The supporting arm was braced as shown and pivots about the retaining bolt so that the angle of the share can be adjusted to suit soil conditions. Also shown in Fig. 3 is a Ferguson stabilizing plate which was fixed to the land side of the cultivator partially to counteract the side draught. Fig. 2 shows how the front of the cultivator was braced so that the hitch could be moved towards the share and side draught reduced. In its present form the implement shows no tendency to " crab " even when working at its full depth. An improvement it is hoped to incorporate for the 1951-52 season is a wider tyre for the off-side cultivator wheel, which tends to sink rather deeply in soft ground.

Rather a large gang is required to keep the tractor busy, but by mustering all hands for a day or two's lifting and bedding enough material can be got up to keep the dispatch department going for some time. Further, as so much root is obtained by this method, pulling can be done by unskilled labour provided that the labelling and bedding is done by competent men.

The second implement to be described arose from the suggestion that a cabbage planter might perhaps be used to cut the grip required for planting bedded rootstocks and cuttings. A cabbage planter furrow opener was accordingly obtained but it proved unsatisfactory. However, after much experimenting the implement shown in Figs. 4 and 5 was evolved. This consists of a revolving grip cutter with supports and scrapers, a tray for carrying bundles of stocks and/or ballast, and a special rim fixed to the tractor wheel which firms in the first row of plants whilst the grip for the second row is being cut.

The grip cutter is built up from two 22 inch harrow discs welded together at the rims and pinched together by two large nuts and washers on the axle to which it is thus rigidly fixed. The whole revolves on bearings in the two vertical support arms, which are of $\frac{3}{4}$ inch mild steel. The scrapers, which must be a close fit, are welded to the same supports. The tray is of wood and can be of any convenient size but must be rigidly fixed to the cultivator frame as a good deal of ballast is needed to force the grip cutter into the ground. This is provided in part by bags of soil and in part by a man sitting on the tray, who drops off the bundles of stocks at the required intervals as shown in Fig. 6. The rim, which closes the grip and firms in the plants, is fitted in place of the outside set of spade lugs on the near side tractor wheel and is shown in Fig. 7. It consists of a piece of 3 inch by $\frac{3}{8}$ inch angle iron bent to conform to the shape of the wheel with a 2 inch by $\frac{3}{8}$ inch strip of mild steel welded to the outer edge

so as to make an angle of about 30° with the rim of the wheel. These dimensions work quite well but may need to be varied to suit other soil conditions. The distance between rows can be varied by adjusting the tractor wheels. In the spring, when the ground has settled, a very shallow furrow is turned over against the base of the stocks to fill in the groove left by the press rim. This prevents the plants being dried out by the March winds.

Again rather a large gang is needed to keep the tractor going but the work of putting the stocks into the grip can all be done by women and the slow and arduous job of cutting a grip by hand is entirely eliminated (Fig. 8). Up to 20,000 stocks have been bedded in by a gang of twelve women in a day.

A third attachment to be described is of interest only to those who have any considerable area of stoolbeds to grub but is cheap and easy to make and has paid for itself many times over at the Research Station. The stool-grubber consists merely of a stout share with supporting arms which can be fixed in the centre of a cultivator from which all the tines have been removed (Fig. 9). The tractor straddles the rows to be grubbed and the attachment makes a U shaped cut and loosens the stocks which can then be pulled up by hand when convenient. The share is an old " Oliver " potato digger share bent up at the ends and the supports are of 2 inch by $\frac{3}{8}$ inch mild steel.

All these attachments were built up in the Farm Workshop with the exception of the press rim, which was constructed by a local engineering works.

The writers wish to acknowledge their indebtedness to Mr. R. J. Garner for many helpful suggestions.

Summary.

A brief description is given of three implements devised at the research station to mechanize the lifting of nursery trees and rootstocks, the bedding-in of rootstocks and the grubbing of stool and layer beds.

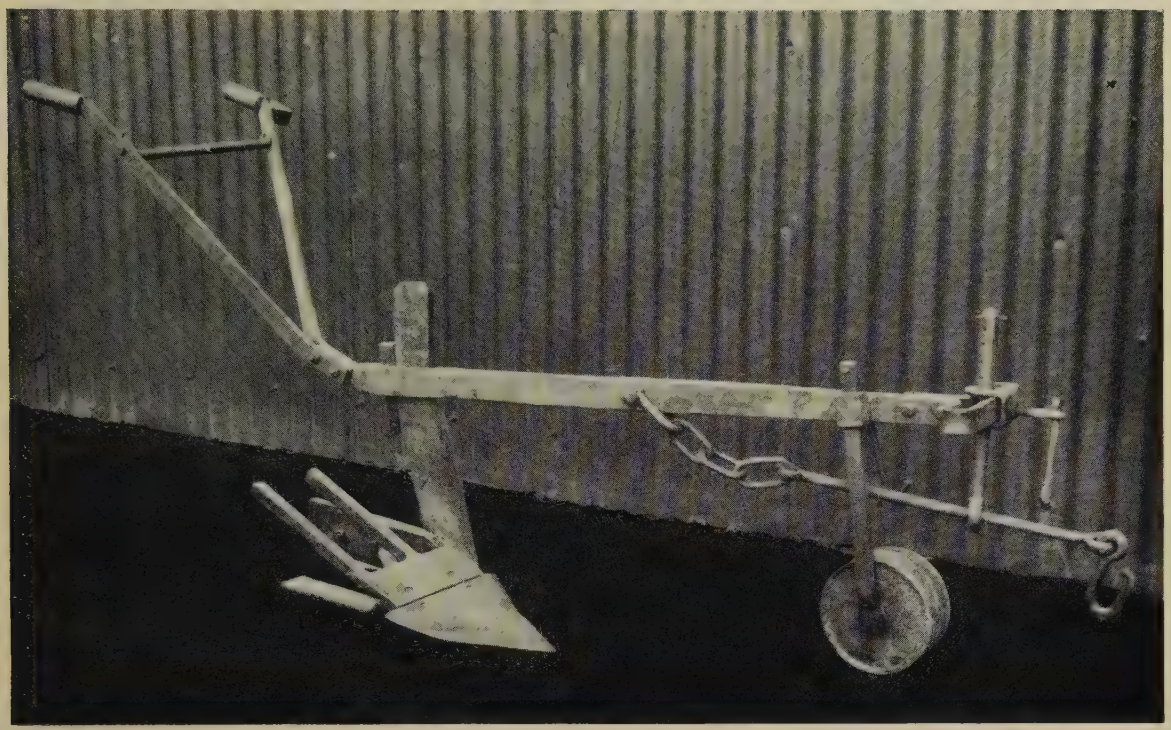


Fig. 1.
Tree-lifting plough as imported from Germany in 1945.

Fig. 2.
Cultivator adapted for lifting nursery material showing share and lifting prongs, share support arm bracing, front bracing and hitch. Arrow indicates retaining bolt about which the implement pivots.

[*face p.* 202

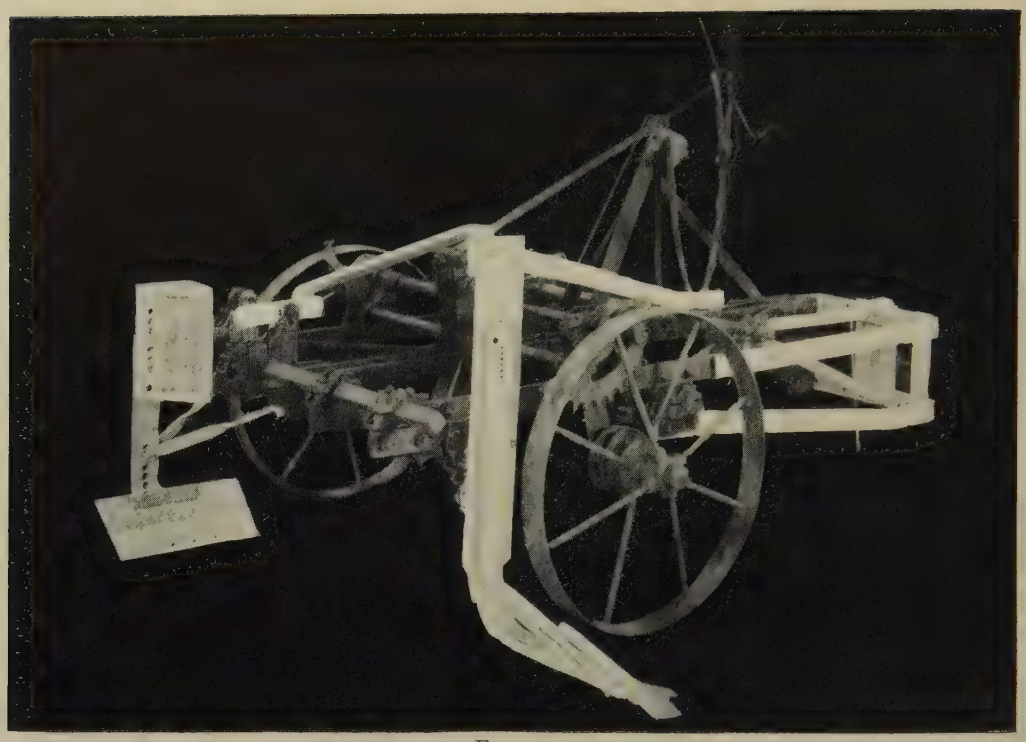


FIG. 3.
Back view of lifting implement showing stabilizing plate.

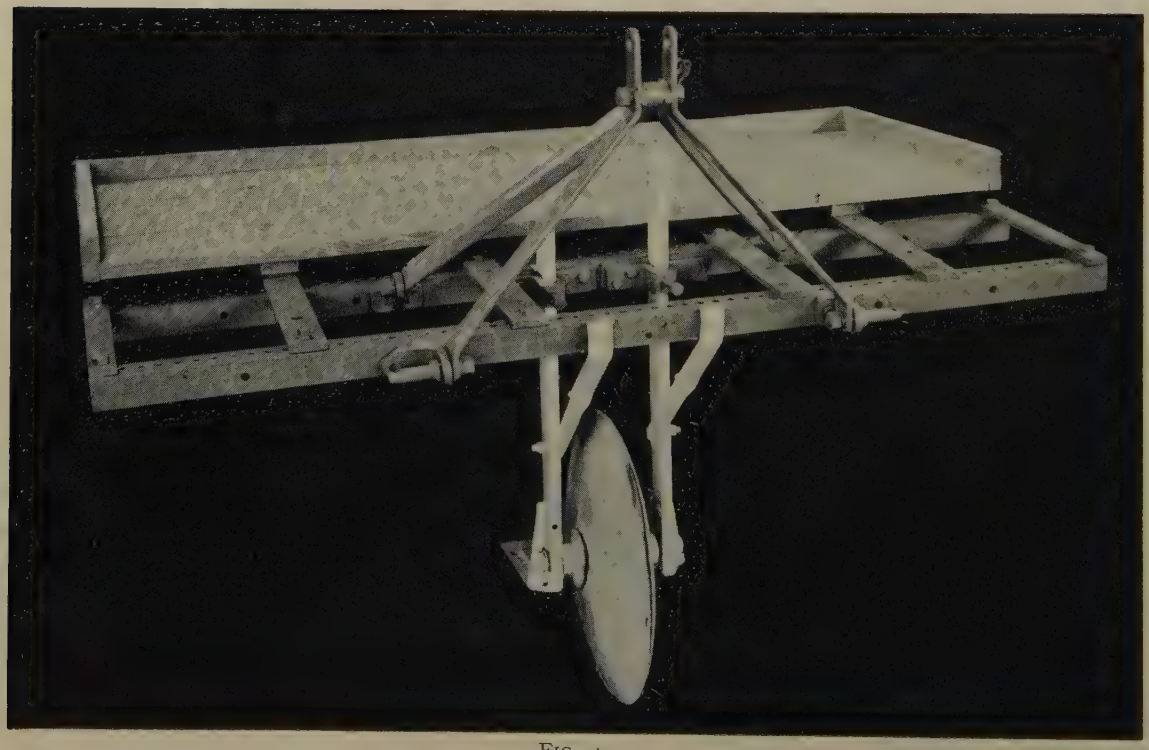


FIG. 4.
Stock planting implement showing grip cutter with supports and bracing, and ballast tray.

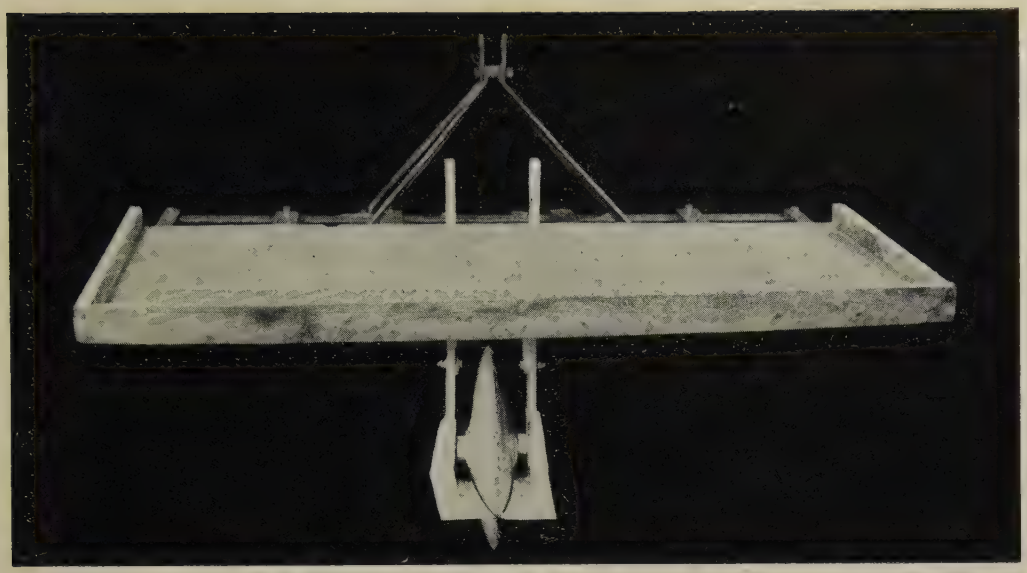


FIG. 5.
Back view of planting implement showing scrapers.

FIG. 6.
Planting implement at work. Grip-cutter forced into the ground by the weight of the man, the rootstocks and the bag of soil on the tray. The press-rim can be seen at work.

FIG. 7.

Press-rim showing holes for bolting it to tractor wheel.

FIG. 8.

Women placing rootstocks in grip made by tractor on previous run.

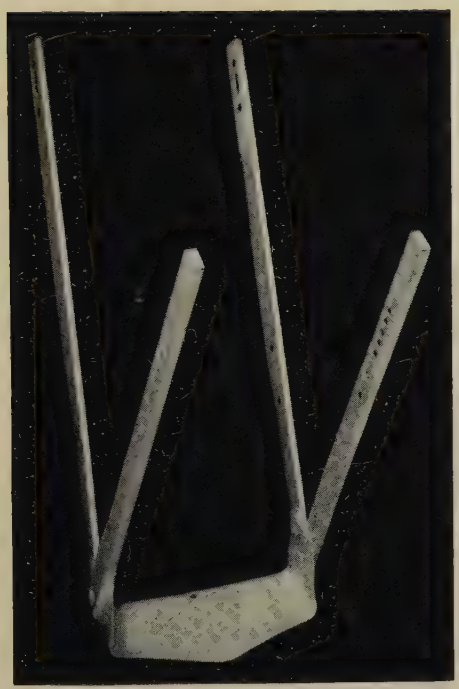


FIG. 9.
Stool-grubber for attaching to cultivator frame.

RASPBERRIES IN SCOTLAND*

By C. H. CADMAN and C. A. WOOD†

Introduction.

With the lifting of war-time cropping restrictions, rising prices and official encouragement of soft fruit planting have led to a rapid increase in the raspberry acreage of the United Kingdom. In Scotland, where during the past half century raspberry growing has become an important and highly localized industry, plantations have increased from some 4,000 acres at the end of the war to 6,190 acres in 1949, thus approaching the peak figure of 6,454 acres reached in 1937. A considerable acreage of new plantations has still to come to full bearing, so that, whilst the estimated output in 1949 was only 6,500 tons, the crops in 1950 and 1951 may not fall far short of the 10,000 tons produced in 1937. Although costs of production were then lower, market prices per ton were at only about one-third their present level. Recent warnings in the horticultural press of an approaching saturation point in soft fruit planting are not unheeded, growers generally being apprehensive of a fall in fruit prices to a level that would be uneconomic.

The bulk of the Scottish crop is grown in the eastern area, mainly in Angus, East Perthshire and Fife, and is absorbed principally by the jam trade, a smaller proportion being used for canning and quick-freezing. The output from the Clyde Valley district of Lanarkshire, the second important area, supplies mainly the dessert fruit markets of Glasgow and England. The consequences of over-production, such as occurred in Scotland in 1930 and 1931, are still a painful memory, and growers are anxiously seeking some assurance of future stability. For this, many are looking to the markets offered by the newer methods of processing.

Such economic problems are, however, not peculiar to Scotland. In part, their solution would seem to lie in utilizing every means of increasing the rate of output *per acre*, at the same time reducing production costs and growing the quality of fruit demanded by the canning, quick-freezing and dessert fruit markets. Choice of variety and of planting-cane are thus of vital importance, and the purpose of this review is to summarize information on these two questions that may be of value to growers and advisers. Whilst much of what follows is applicable throughout the United Kingdom, statements on the finer points of fruit quality and disease resistance are necessarily based on experience in Scotland, more particularly in the eastern districts.

Planting stocks—The significance of virus diseases.

Whilst purely economic factors have, from time to time, seriously depressed Scottish raspberry growing, the industry has also suffered at certain periods through the loss of vigour and cropping capacity of its staple varieties. Recent research has provided ample evidence that this occurs largely through the spread and accumulation of virus diseases, the dissemination of which is greatly accelerated by indiscriminate propagation of planting cane.

The presence of virus diseases in raspberries can be detected only by the visible leaf and cane symptoms expressed by infected plants, and accurate diagnosis of all but the most obvious forms of infection is often a difficult matter for the untrained eye. Indeed, the majority of modern varieties fail to express visible leaf symptoms when infected with certain virus complexes highly injurious to health and vigour. For these reasons it is becoming clear that we shall have to depend more and more on supplies of planting stock derived initially from canes carefully tested for virus content under controlled conditions.

None of the raspberry viruses so far discovered has proved to be transmissible by such mechanical means as pruning, or other cultural operations. Evidence has been published, however, that the two species of aphids common on raspberries, *Amphorophora rubi* Kalt. and *Doralis* (*Aphis*) *idaei* V. d. G., can transmit certain viruses. These two insects are thought to be the principal vectors under field conditions, but there is, as yet, no promise of control of virus infection through the control of aphids.

Two viruses cause extremely severe and obvious diseases. One of these, Leaf Curl (1, 4) appears to be confined to Scotland and is lethal to the varieties Norfolk Giant, Malling Enterprise, Malling Notable and Malling Jewel. The second, Rubus Stunt (dwarf) (5), is more widespread in England.

* Reprinted by permission from *Scientific Horticulture*, Vol. X.

† Scottish Raspberry Investigation, financed by a grant from the Agricultural Research Council, to whom acknowledgement is made.

The flowers on canes of certain varieties affected by this disease are sterile, whilst normal growth of young canes gives place to a mass of spindly growths often only a few inches high.

The common " mosaics " of raspberries are due principally to infection by members of a group of viruses, here termed Group I, that cause leaf symptoms varying from mild " yellows " to the severe chlorosis described by Harris (3) as " Mosaic 1 " (Figs. 1-5). All varieties, so far as is known, show distinguishable symptoms on infection with these viruses. The more severe mosaic symptoms are associated with an obvious reduction in vigour of growth.

There is a second large group of viruses, somewhat imperfectly known, that is thought to play a major role in the " symptomless degeneration " of so-called " carrier " varieties. The several viruses of this group, here termed Group II, include those causing diseases of the " Mosaic 2 " type (3) on varieties Norfolk Giant, St. Walfried and Burnett Holm Seedling (Fig. 6). All other current varieties fail to express distinguishable symptoms when infected with Group II viruses, the presence of which can, therefore, be detected only by graft-tests to more sensitive hosts. Whilst it is possible, with experience, and certainly advisable, to eliminate viruses of Group I from stocks by careful roguing, the spread of viruses of Group II in the majority of varieties cannot so be checked.

In the course of testing-work carried out at Dundee during recent years, a certain amount of information has been accumulated on the state of health of current stocks of the more prominent raspberry varieties. This, together with notes on reactions to virus and other diseases, is incorporated in the varietal descriptions given later in this review.

Propagation of cane.

The clearance of surplus cane from young fruiting plantations is a necessary routine cultural practice which has, unfortunately, become a firmly established means of obtaining cane for new plantings. Whilst such cane is often satisfactory from other standpoints, fruiting plantations can rarely provide supplies of good quality cane from the point of view of freedom from virus and other diseases. For reasons already given, control of virus diseases in raspberries by the roguing of visibly infected plants is of very limited efficiency : moreover, roguing is generally quite impracticable in fruiting plantations. Continued propagation from such plantations therefore tends inevitably to accelerate the deterioration of stocks through virus infection.

For this reason, a more general adoption of the cane-nursery method of propagation (6), with its attendant advantages, is greatly to be welcomed. Both the Department of Agriculture for Scotland and the Ministry of Agriculture and Fisheries issue annually a list of certified stocks of certain varieties propagated by this method, and there is no doubt that these are the best sources of supply for intending planters.

A word of warning should, however, be addressed to those intending to specialize in the production of planting cane, as distinct from fruit production. In recent years of rapid expansion canes have found a ready market ; but the outlet for cane produced by specialist growers is bound, in the future, to be limited. The introduction of new and improved varieties has encouraged speculation in what is a relatively new venture, but as the demand for these varieties becomes satisfied the returns from cane production are certain to decrease. This position has been reached, in Scotland, with the variety St. Walfried, and may soon arise in the case of Malling Promise. In the writers' opinion there will, in the future, continue to be a demand for high-grade certified cane for the replacement, annually, of a portion of the total fruiting acreage. It seems clear, however, that this need will be satisfied by a relatively small acreage of cane nursery.

Varieties.

Choice of variety is of pre-eminent importance, and is becoming increasingly influenced by the question of fruit quality. Not all the heavily cropping varieties suitable for the jam trade are capable of producing the high quality product demanded by the dessert fruit, canning and quick-freezing trades. Other important factors are growth habit, adaptability to a wide range of growing conditions, resistance to spring frosts, and ease of picking. Of these, the last two are of particular significance in Scotland.

The general deterioration of stocks of Lloyd George in the late 'thirties deprived the industry in the East of Scotland of one of its most successful all-purpose varieties. Of the limited range of substitutes then available, Norfolk Giant alone may find a permanent place, mainly on account of its good points as a canning and quick-freezing berry. The work of Mr. N. H. Grubb, at East Malling Research Station, culminating in the recent production of a series of valuable new varieties, has been recognized as a major contribution towards the rapid recovery by the industry of its pre-war status. The more important of these introductions are discussed in detail below. As a result of Mr. Grubb's work, there

Fig. 1.
Vein chlorosis on Norfolk Giant.

Fig. 5.
Severe yellows on Norfolk Giant.

Fig. 2.
Severe vein chlorosis on Malling Promise.

Figs. 3 and 4.
Veinbanding on Malling Promise and Malling Notable respectively.

Figs. 1-5.
Symptoms caused by Group I viruses.

[face p. 204

FIG. 6.
Symptoms caused by Group II viruses : severe Mosaic 2 on Norfolk Giant.

should be no lack of good new varieties for some years to come; but there is undoubtedly scope for the production of a wider range of high quality varieties suitable for special types of processing.

The varieties described below include all those at present of commercial importance in Scotland and, largely, other parts of Britain. Excluded are certain varieties, among them Preussen, Devon, Pyne's Royal and Red Cross, which, though still favoured in certain districts or for particular purposes, are no longer readily obtainable in good health and vigour and have largely been superseded by newer introductions. Also excluded are certain fairly well-known recent seedlings, such as Malling Exploit, which are still incompletely tested and not yet available for large-scale planting.

The notes on canning and quick-freezing qualities are based on information kindly made available by a number of commercial firms. With the exception of Burnett Holm Seedling, canning tests on all the varieties described have been carried out over a number of years, and the assessments are therefore fairly reliable. Quick-freezing tests have been carried out only during the 1949 season, and the results must, therefore, be regarded as tentative and subject to confirmation.

Lloyd George.

This variety originated in Britain as a chance seedling and was introduced to commerce some thirty years ago.

Healthy stocks are highly vigorous, producing an abundance of canes which become well furnished with fruiting laterals, often almost to ground level. The variety is among the earliest to ripen and has a fairly long picking season. The berries are very large, conical, firm, bright in colour when fully ripe, but liable to turn dark if allowed to over-ripen. The fruit parts easily from the plug, but is often much hidden by foliage.

Commercial qualities. In good health, Lloyd George is one of the heaviest-cropping of raspberry varieties. Yields in the past sometimes exceeded 4 tons per acre, and similar results have been obtained recently from healthy selections. The variety is considerably susceptible to late spring frosts, but when seriously affected shows a marked tendency to recover by forming late-fruiting secondary laterals. It is a general purpose variety, favourably reported upon for both canning and quick-freezing.

Health of Stocks. Current commercial stocks in this country are extensively virus infected, and none can be recommended with confidence. The New Zealand stock, which, it is hoped, will be available in some quantity in 1950, is free from serious virus infection and appears to be very vigorous.

The variety shows symptoms, sometimes difficult to detect, when infected with the viruses of Group I, but fails to express visible symptoms when infected with Group II viruses. It is sensitive to Rubus Stunt and shows conspicuous leaf chlorosis and dwarfing of canes when infected with Leaf Curl.

Norfolk Giant.

This variety originated as a chance seedling in Norfolk. It has been extensively grown in East Anglia, and later elsewhere, since about the time of the First World War.

It produces very strong, lengthy canes and shows a marked " stooling " habit, " spawn " growth being comparatively scanty. Plantation work in summer is often obstructed owing to the spreading growth of the young canes. The fruiting laterals are long, and seriously apt to break off at the base. Ripening is late, the picking season in Scotland often extending well into September. The berries are of medium size (often becoming small late in the season), firm, fairly bright in colour, conspicuous and usually easy to pick.

Commercial qualities. Norfolk Giant, in Scotland, generally yields an average crop. Its late flowering enables it partly to escape frost, but picking is liable to be terminated by broken weather or by difficulty in obtaining labour near the end of the season. The fruit is much favoured for canning and satisfactorily reported upon for quick-freezing.

Health of stocks. This variety is eligible for inspection under the certification schemes of the Ministry of Agriculture and the Department of Agriculture for Scotland. Certified stocks entirely free from visible mosaic symptoms may, for practical purposes, be regarded as healthy, since the variety is sensitive to nearly all the known raspberry viruses.

Norfolk Giant, under Scottish conditions, is very susceptible to the fungus disease Cane Spot.

St. Walfried.

This variety was raised in Holland by Dr. I. Rietsema, from a cross between Lloyd George and the variety Hornet.*

Healthy stocks are vigorous and form an abundance of canes, which are generally well furnished with short, strong fruiting laterals. The crop ripens from early to mid-season. The berries are mainly

* The variety used is believed to be that described by Grubb (2) as Hornet " A ".

conical, often very large, and tend to be crumbly when under-ripe and soft when fully ripe. If left to hang after ripening, they turn very dark and often adhere tightly to the plug, making picking difficult.

Commercial qualities. Although capable of yielding a fairly heavy crop, St. Walfried is unduly susceptible to spring frosts. Plantations, also, are sometimes slow to become well established. The fruit, owing to its soft texture and dark colour, is generally unsuitable for basketing and is grown mainly for the jam trade.

Health of stocks. Although this variety is eligible for inspection under both the English and Scottish certification schemes, sound stocks remain scarce. The majority of current stocks are extensively virus infected and variable in performance. The variety expresses symptoms when infected with viruses of Group I, with some of those of Group II, or with Rubus Stunt, and shows severe mosaic and dwarfing when infected with Leaf Curl. In Scotland it is highly resistant to Cane Spot.

Newburgh.

This variety was raised at the New York State Agricultural Experiment Station, U.S.A., from a cross between the American varieties Newman and Herbert.

It produces tall, erect canes with strong, short or medium length fruiting laterals. There is a tendency for the lower buds to remain dormant. The crop ripens from mid to late season, the berries being generally large, almost round, and of a bright, attractive colour, but showing a marked tendency to crumble, especially on some soils and in some seasons. The fruit is conspicuous, and easy to pick unless very crumbly. It will hang on the canes for an appreciable time without deteriorating.

Commercial qualities. An average or even poorly cropping variety in Scotland, Newburgh seems to succeed better in the south of England. It is favoured for the dessert trade, but the new Malling varieties derived from it may prove superior. Its crumbly texture makes it unsuitable for canning or quick-freezing.

Health of stocks. No commercial stock of Newburgh hitherto tested has proved to be free from infection by Group II viruses. The variety appears to be highly virus tolerant, i.e., it withstands severe virus infection without loss of vigour. It does, however, show mosaic symptoms when infected with one of the Group I viruses. Its reactions to Rubus Stunt and Leaf Curl are not yet known.

Burnett Holm seedling.

This variety originated in the Clyde Valley, where it has been grown for well over twenty years.

Good stocks produce tall, somewhat slender canes ; abundantly, on some of the lighter soils in Clydeside, but rather scantily in some eastern parts of Scotland. The fruiting laterals are mainly short and very sturdy. Ripening is from early to mid season. The berries, of medium to large size, are roundish, smooth in shape and firm, and remain light red even when fully ripe. Although easy to plug, they hang on the canes for an appreciable time without deteriorating.

Commercial qualities. Burnett Holm is grown mainly in the Lanarkshire area of the Clyde Valley, where conditions appear especially to suit it. Although not outstanding in cropping it possesses good dessert quality and firmness which make it very suitable for the Clydeside fresh-fruit market. It appears to be satisfactory for canning and probably also for quick-freezing.

Health of stocks. Information on the health of commercial stocks of this variety is scanty. The majority of Clydeside stocks appear to be vigorous, and at least one is known to be free from serious virus infection. The variety can be rogued for mosaic symptoms caused by certain viruses of Groups I and II. It is sensitive to Rubus Stunt but its reaction to Leaf Curl is not yet known.

Malling Promise.

This variety was raised from a cross between Newburgh and an earlier seedling derived from Pyne's Royal and Lloyd George.

Current stocks of this recent variety are highly vigorous and produce a great abundance of canes, especially during the first two seasons after planting. The fruiting laterals, though often long, are not seriously inclined to break. Under close-planted conditions the lower buds of the canes have a marked tendency to remain dormant. The crop ripens early. The berries are very large, bluntly conical, and generally bright in colour when fully ripe, though apt to turn dull in dry seasons. Ripening is sometimes uneven, the berries being temporarily green-tipped. The fruit is a little soft when fully ripe. It is conspicuous, and generally easy to pick, although breaking of the stalks sometimes causes plugs to remain in the berries.

Commercial qualities. Malling Promise is one of the highest cropping of modern varieties. Although producing leaves and flower-buds early, it has so far proved less frost-susceptible in Scotland than Lloyd George or St. Walfried. The fruit, owing to its tendency to softness, is generally unsuitable

for the dessert trade unless picked slightly under-ripe. It is also poorly reported upon for canning and quick-freezing. The variety has been considerably planted in the east of Scotland since the war, its high yield commending it for the jam trade and its earliness tending to reduce the risks of a late season.

Health of stocks. Most current commercial stocks of Malling Promise are believed to be substantially free from serious virus infection, though certified stocks should be considered the most reliable sources of planting cane. The variety shows mosaics, sometimes detectable with difficulty, on infection with certain Group I viruses. It fails to show clear symptoms on infection with Leaf Curl or the Group II viruses, but is sensitive to Rubus Stunt.

Malling Landmark.

This variety was raised from a cross between Preussen and Baumforth's Seedling " A ". It was formerly known as Seedling " L ".

It produces a fair abundance of tall, strong, very spiny canes of almost erect habit, well furnished with long, very stout fruiting laterals. The crop ripens late, though earlier, in Scotland, than that of Norfolk Giant. The berries are large or very large and almost round, and retain their bright, medium-red colour well after ripening. The fruit is distinctly soft in texture, and the flavour more acid than that of any other variety here described. The berries are very conspicuous, but often difficult to pick owing to their firm attachment to the large, roundish plug. This feature varies seasonally, but there are indications that the fruit is more acid in flavour and more difficult to pick in Scotland than in the south of England.

Commercial qualities. Malling Landmark yields, in most districts, an outstandingly heavy crop, but the fruit is apt to spoil seriously in a wet season. The thorny nature of the canes, frequent difficulty of picking and soft texture of the fruit are considerable faults. Generally speaking, the variety is suitable for the jam market only.

Health of stocks. The situation with Malling Landmark is somewhat confused. Current vigorous stocks are seldom entirely free from symptoms of virus infection. Although exhibiting a considerable range of mosaic symptoms, the variety is non-expressive of certain Group II viruses. The commonest form of mosaic is due to a virus frequently or invariably present in Norfolk Giant, and it is inadvisable, therefore, to plant these two varieties in close proximity to each other. Malling Landmark is extremely susceptible to Rubus Stunt, but its reaction to Leaf Curl is not yet known.

Malling Notable.

This variety was raised from a cross between Preussen and Lloyd George. It was formerly known as Seedling " N ".

The healthiest stocks are often only moderately vigorous, although producing a fair abundance of canes. These are of slightly spreading habit and well furnished with short, stiff fruiting laterals. The crop ripens from second-early to mid season, with a short picking period. The berries are medium to large in size, short-conical, and usually firm in texture, and generally remain bright in colour after ripening. The fruit is conspicuous and very easy to pick.

Commercial qualities. Malling Notable generally produces only an average crop, but has done very well at certain places in Scotland and in the north of England. The fruit is sufficiently firm for basketing, but present information from canning and quick-freezing tests indicates that it is only of moderate quality for these purposes.

Health of stocks. Available commercial stocks, though vigorous, appear to be wholly infected with Group II viruses. The variety shows clear and often severe mosaic symptoms when infected by viruses of Group I, and is killed by Leaf Curl. It is known to be sensitive to Rubus Stunt.

Malling Enterprise.

This variety was raised from a cross between Preussen and an earlier seedling. It was formerly known as Seedling " E ".

On many soils it is a sparing producer of canes, a fault which may possibly be overcome by close planting. The canes are often tall and stout, and are apt to suffer damage from wind before tying in. The fruiting laterals are also stout, and fairly long. Ripening is from mid to late season. The berries are large, roundish, firm, and of moderately bright colour, though tending to become dark when fully ripe ; but this last fault is less marked than in Lloyd George or St. Walfried. The fruit is conspicuous and easy to pick.

Commercial qualities. Though often yielding an average crop, Malling Enterprise is apt to be disappointing under field conditions owing to scanty cane production. It usually succeeds well in gardens, producing very tall canes under sheltered conditions. It is among the better of the Malling

varieties in dessert quality and present reports indicate that it is suitable for canning and fairly satisfactory for quick-freezing.

Health of stocks. The best available commercial stocks of this variety, though vigorous, appear to be wholly infected with Group II viruses. The variety shows mosaic symptoms, sometimes detectable with difficulty, when infected with Group I viruses, and is killed by Leaf Curl. It is sensitive to Rubus Stunt.

Malling Jewel.

This is a sister variety of Malling Enterprise and was formerly known as Seedling " J ".

This variety produces a fair abundance of smooth, almost erect canes of good height, well furnished with short, sturdy fruiting laterals. The crop ripens from early to mid season. The berries are generally large (though tending to decrease in size during the season), conical, very firm, and of a bright red colour when ripe. They have a slight tendency to darken if allowed to become over-ripe. The fruit is exceptionally easy to plug and mostly conspicuous, though some berries are hidden by the curled leaves of the laterals.

Commercial qualities. This variety has cropped above the average in recent Scottish trials, and may be commended for its erect growth habit, almost spine-free canes and distinct ease of picking. Flowering a little later than Lloyd George, St. Walfried, Malling Notable, and other varieties, it may to some extent escape frost, and it still ripens at about the same time as these varieties. It is favourably reported upon for both canning and quick-freezing.

Health of stocks. Malling Jewel resembles Malling Enterprise in its virus reactions, and current stocks of the two varieties are of similar status.

Acknowledgements.

The writers are indebted to Messrs. Chivers & Sons, Ltd., Messrs. Fromac Ltd., and Messrs. Smedley's Ltd. for tests and information on the canning and quick-freezing qualities of raspberry varieties described in this paper.

Summary.

This popular survey includes descriptions of the raspberry varieties of commercial importance in Scotland and notes on the health of available stocks of each.

References

(1) Department of Agriculture for Scotland (1949). Raspberry diseases in Scotland. Advisory Leaflet No. 7 (New Series).

(2) Grubb, N. H. (1922). Commercial raspberries and their classification. *J. Pomol.*, **3**, 1-25.

(3) Harris, R. V. (1940). Mosaic Disease of the raspberry in Great Britain. II. Experiments in transmission and symptom analysis. *J. Pomol.*, **17**, 318-43.

(4) ———, Bryce, A. D. and Foister, C. E. (1943). A leaf curl disease of raspberry in Scotland. *Rep. E. Malling Res. Sta. for 1949*, 48-50.

(5) Prentice I. W. (1951). Rubus Stunt ; a disease of raspberries. *J. hort. Sci.*, **26**, 35-42.

(6) Wood, C. A. (1949). Raspberry cane nurseries. *Rep. E. Malling Res. Sta. for 1948*, 141-7.

VIRUS DISEASES OF SWEET CHERRIES

By A. F. POSNETTE

Virus diseases of cherries are prevalent in the U.S.A. and Canada and recent reports suggest that they are causing serious losses in Holland and Switzerland. There has been considerable interchange of varieties between England, America and Continental Europe in the past, so that it would be surprising if we had avoided introducing viruses from abroad. As wild cherry stocks, often suckers from the roots of old trees, have been used for centuries to propagate our varieties, we should expect also to find " indigenous " virus diseases in a crop so prone to infection. Now that vegetatively propagated stocks such as F12/1 are in general use, particular care should be taken to see that these stocks are kept virus-free, otherwise virus diseases will soon spread from them to all our commercial varieties.

With a few important exceptions, known virus diseases of cherries spread slowly, or not at all, from tree to tree in orchards ; most of the increase in infection has been due to the use of infected scion wood. It is therefore of primary importance that healthy trees should be chosen to supply bud and graft wood, labelled, and then propagation so arranged that any symptoms which appear on the maidens can be traced back to their parent tree. In this way, growers should be able to select mother trees free at least from those viruses that produce visible symptoms on cherries. The task of providing a completely healthy stock rests with research stations where sensitive varieties can be used to test for " masked " viruses.

No organized survey for cherry viruses has yet been attempted in England but as a result of reports by growers and N.A.A.S. officers I have been able to inspect about fifty orchards during 1949 and 1950. Not one of these has been entirely free from virus symptoms. At this early stage in our research on cherry viruses there are probably many symptoms of which we are still unaware. We do not know how different varieties react, which are tolerant and which are sensitive to the different virus diseases. We do know that some viruses cause noticeable symptoms only at certain stages of infection and growth of the tree, and at other times may cause a loss of crop and vigour, which might be attributed to many other causes.

Symptoms.

This bulletin is intended to give growers a general picture of virus symptoms in cherries as at present recognized. Undoubtedly later work will fill in many details and modify this picture, but it is felt that some guide should be given now to those wishing to avoid propagating infected trees.

It is possible to divide the leaf symptoms seen in English orchards into five groups. It must be stressed here that we are classifying the *symptoms* and not the viruses nor the diseases. Several distinct viruses may be causing similar symptoms, and different symptoms may be caused by one virus in different varieties or in the same variety at different stages of infection. It is also probable that some of these symptoms are not caused by a single virus, but are the combined effect of two or more viruses in one plant.

With these reservations clearly in mind, the symptoms observed can be grouped as follows :—

1. *Rosette* (Fig. 1) caused by stunted growth, the short internodes bringing the leaves close together. The leaves are usually narrow and crinkled, and often mottled (Fig. 2).

2. *Rasp-leaf*, in which the leaves are thick and harsh, toothlike outgrowths on the under surface giving a rasp-like feel (Fig. 3). These outgrowths, or enations, are the diagnostic character of this group, but they are often accompanied by some narrowing of the leaf and rosetting (Fig. 4).

3. *Tatter-leaf*, caused by the death of areas in the leaf. This symptom occurs in varying degrees, from a mild condition in which the dead areas are small and distinguishable from bacterial spots only by their slightly lighter and redder colour (and of course by the absence of bacteria), to a severe state in which nearly all the leaf is destroyed (Fig. 5). This symptom is most conspicuous when the brown dead areas are still attached to the leaf. The tree then looks as if it had been scorched by fire or damaged by spray, an illusion heightened by the fact that only one side or one bough of a tree may show symptoms. After the dead areas have dropped out, the leaves remain as tattered remnants, but the tree is not very conspicuous because by this time new leaves have developed on the extension growth and this new foliage usually remains normal until late in the summer when symptoms may develop, though not as severely as on the spring leaves.

4. *Vein-clearing*, usually associated with crinkling and an uneven margin to the leaves (Fig. 6) which droop and are slightly rolled.

5. *Mottles* and various patterns comprise the largest group of virus symptoms. They can be divided into vague mottle, ring-spots (Fig. 7), lines or bands (Fig. 8) and coloured patterns (Fig. 9). In the latter group, brick-red spots and rusty-brown blotches are the commonest.

Time of inspection.

Scion material. Since some viruses cause distorted or small fruit, it is important that the trees to be used as sources of scion wood should be inspected just before the fruit is to be picked. This is an excellent time for seeing leaf symptoms on spur leaves but mottles and tatter seldom develop on the leaves on the extension growth until late in the summer, if at all.

Rootstocks. The best time for roguing rootstocks is at budding time. The spur leaves on the one-year-old wood should be examined more carefully than the leaves on the extension growth ; in stool beds after earthing-up only this extension growth is visible and roguing cannot be done efficiently.

One warning : when a bud or graft fails to take, either discard the rootstock entirely or rework it with the same variety again. Even though the graft failed, a virus may have passed into the stock—viruses frequently cause bud failure—so a worked stock should never be put into a stool bed and propagated.

Summary.

The virus symptoms seen on sweet cherry trees in England during 1949 and 1950 are illustrated and briefly described in five groups : rosette, rasp-leaf, tatter-leaf, vein-clearing, and mottle.

Fig. 1.
Two-year-old Schrecken, healthy (left), and with rosette (right).

[face p. 210

THE RASPBERRY CANE MIDGE AND ITS CONTROL

By R. S. PITCHER

The Raspberry Cane Midge (*Thomasiniana theobaldi* Barnes) belongs to the large family of Gall Midges (*Cecidomyidae*). It is not, however, a typical member as its larvae live under the rind of raspberry canes without forming a gall. Here they cause only superficial injury, their importance lying in the fact that their feeding renders the cane susceptible to invasion by various fungi.

Biology.

Only brief outline will be given here as a preliminary paper has already appeared* and a scientific account is now in the press. The midge passes the winter as a resting larva in a cocoon in the surface soil around the base of the stools. Pupation occurs in the spring, the majority of midges emerge in early May and quickly begin to lay eggs on the young green canes (spawn), which are then about a foot high. The female midges, which are incapable of piercing sound plant tissue, lay their eggs in breaks in the rind of the cane. Accidental injury provides few opportunities for this but the rind of some varieties of raspberry frequently splits extensively in the course of normal growth and it is in such sites that the majority of eggs are laid. The legless larvae feed under the peeling rind, causing localized brown patches (see Fig. 1), until they are about 3 mm. in length and salmon pink in colour. They then wriggle out of the splits and fall to the ground, pupating in a cocoon at the base of the canes. A second and much larger generation occurs in July and a third, of variable size depending on the season, in late August and early September.

Fungal invasion of the canes.

Canes that have been damaged by the midge very frequently suffer fungal invasion. This may occur after each generation but it is most marked and dangerous following the second. The fungi enter the superficial midge lesions causing corresponding patches of deeper injury extending as far as the pith of the cane. If midge attack has been light these patches will be few in number and relatively unimportant but canes with many midge lesions will have a large amount of the conducting tissue destroyed and usually die before they can bear fruit in the following season. Between these extremes there will be other canes that will not die, but will carry a reduced crop. The dead fruiting canes are often the grower's first indication that midge has been present and in the past they have frequently been ascribed to Cane Blight Disease (caused by the fungus *Leptosphaeria coniothyrium* (Fckl.) Sacc. entering through a wound). To distinguish these two diseases it is proposed to give the name of " Midge Blight " to the death of fruiting canes that follows an attack of cane midge on the spawn of the previous year. It is possible, although not always easy, to separate them by an examination of the dead canes but if there is doubt an inspection of the spawn during the following July will quickly show whether or not the midge is present.

Economic importance and distribution.

Fortunately, the midge is by no means a universal pest of raspberries ; it is not known to be present in Britain outside the South and Midlands and even in these districts it is confined to susceptible varieties such as Newburgh and Malling Enterprise. Norfolk Giant and Malling Landmark are very resistant ; most other varieties fall between these extremes. The damage caused can be locally serious as susceptible varieties often lose 50 per cent of their best canes, while losses of 75 per cent and upwards have been recorded.

Control.

Fungicidal sprays have consistently proved valueless, but as cane death of this type occurs only after severe midge damage a control of the latter will suffice. Field control measures have been directed against the three following stages of the life-history of the midge.

* Pitcher, R. S. (1948). *Rep. E. Malling Res. Sta. for 1947*, 141-3.

(1) The overwintering larvae in the soil : winter applications of tar oil and naphthalene have failed to give a lasting control.
(2) The midges which emerge in the spring : this has proved the most successful approach.
(3) The larvae on the cane : parathion is the only really effective insecticide, but damage to the cane will already have begun at this stage so it is inadvisable to leave control measures as late as this.

When planning the control of the midges that emerge in the spring two points must be borne in mind :—

(*a*) The female midges begin to lay eggs within an hour or two of emergence.
(*b*) The emergence period extends over a fortnight at least and may be as long as six weeks ; three weeks is probably an average figure.

Thus, if the spray applications are to be kept down to a reasonable number the chosen insecticide must be both quick acting and persistent, properties that are rarely found combined. DDT, for example, has the necessary persistence but experiments in 1947 showed that, even with good timing, a spray deposit on the spawn did not prevent an appreciable number of eggs being laid and by the end of the season both sprayed and unsprayed plots were equally attacked. Subsequent laboratory trials confirmed that neither DDT, BHC nor parathion gave a significant reduction in egg-laying by active female midges. Trials in 1948 showed that if the soil around the base of the canes was also wetted the control obtained by DDT was much improved, while a wash containing BHC gave an even better result. This technique ensured that the midges came into contact with an insecticidal deposit as soon as they emerged in a soft and vulnerable condition on the surface of the soil. The superior control obtained by the use of BHC was in part due to its ability, at this time of the year, to kill some of the eggs and larvae covered by the rind of the canes. It is also possible that it acted as a fumigant against the larvae and pupae in their cocoons in the soil. Trials in 1949 and 1950 confirmed the efficacy of BHC and suggested that a wettable powder formulation was to be preferred. It was also found unnecessary to make a special application of BHC to the soil as the amount of spray falling on it in the course of a thorough wetting of the spawn was adequate, and in 1950 one application gave almost as good control as two. Parathion was inferior to BHC wettable powder in 1949 but was equally good in 1950. The results of the four years trials, which will be published in full elsewhere, show that the degree of control achieved with two applications of BHC wettable powder has varied from 66 per cent to 95 per cent. In 1950 the sprayed plots yielded 2·15 tons per acre as compared with 0·84 tons per acre on the unsprayed plot (variety Malling Enterprise).

Recommendations.

Where midge injury is known to be severe apply two washes of benzene hexachloride wettable powder at 0·1 per cent crude BHC (0·013 per cent γ isomer). A wash of this strength will be obtained by adding 2 lb. of a 50 per cent preparation to 100 gallons of water. Only the spawn need be sprayed and a thorough wetting can be achieved with about 300 gallons/acre. Because of the waxy nature of the canes additional wetter is helpful in securing an even cover. The initial application is usually best made in the first week of May, the second following 10-14 days later (the shorter period in a warm season). If in the past the midge has not been a serious pest the first application alone should suffice. If the midge is not noticed until many first generation larvae are already present on the canes a parathion spray at 0·01 per cent of the commercial product (8 oz./100 gallons of a 20 per cent preparation) will give a good kill. A second application may be necessary to cover the remainder of the emergence period.

Summary.

A brief account is given of the biology of the Raspberry Cane Midge (*Thomasiniana theobaldi* Barnes) and the subsequent invasion of the canes by fungi. As a result of four years field trials two sprays of benzene hexachloride wettable powder are recommended as a control measure.

Fig. 1.
Damage caused by larvae of the second generation of Raspberry Cane Midge.

[face p. 212

CHEMICALS FOR THE CONTROL OF APPLE SAWFLY

By A. H. M. KIRBY

The control of Apple Sawfly by nicotine is not always sufficiently good. It is known that the timing of the spray in relation to the hatching of the eggs is important and weather conditions may well play a part. High temperatures at the time of application do not seem to be of over-riding importance as, in trials in 1950, a 95 per cent reduction in infestation was obtained with nicotine although the maximum temperature on the day of application was only 55° F. Nicotine is essentially a contact insecticide and is usually regarded as non-persistent ; accordingly a search was begun in 1946 for a more lasting insecticide.

The first materials tested were DDT and two Lethanes, but none of these showed any promise, even DDT, applied either at the petal-fall stage or when the eggs were hatching, giving very little control. In 1947 benzene hexachloride (BHC) and HETP were tried. The latter is, of course, not persistent and proved useless, but BHC, even at 2 lb. of the 50 per cent wettable powder per 100 gallons (i.e. 0·01 per cent γ isomer), gave a high degree of control when applied at petal-fall or at egg-hatch.

In 1948 BHC was tried again along with parathion and chlordane, all fairly persistent materials and all worked well when applied at petal-fall or egg-hatch whereas nicotine gave only moderate control.

In 1949, sawfly was very late appearing on our experimental trees and large trees in a commercial orchard were used instead. Various strengths of parathion were compared with nicotine and it was found that parathion gave better and better control as the concentration was increased, reaching 95 per cent reduction by 0·02 per cent parathion, whereas nicotine gave poor results.

In 1950 it was possible to continue the experiments at the research station using BHC, chlordane, parathion and DDT as well as some promising new materials toxaphene, aldrin and dieldrin. In this season all materials used gave over 90 per cent reduction of an infestation that affected over 40 per cent of the blossoms on unsprayed trees. Parathion, dieldrin and aldrin gave a reduction of 99 per cent ; BHC at 2 lb. per 100 gallons gave over 98 per cent and even at 1 lb. gave 93 per cent ; DDT, chlordane and toxaphene all surpassed 93 per cent.

Of these insecticides DDT is too toxic to beneficial insects to use after blossoming, parathion suffers from the same disadvantage as well as being very toxic to man, chlordane is not yet available, aldrin and dieldrin are very new chemicals about which we know little as yet. Toxaphene is now being made in this country and is less objectionable than any of the other substitutes for nicotine listed here ; it may prove to be the insecticide of choice for Apple Sawfly control. BHC is safe to handle and at 2 lb. of a 50 per cent wettable powder per 100 gallons is cheaper than the usual nicotine spray. It is probable that 1 lb. per 100 gallons would give a 90 per cent control, which might be adequate in most cases. One possible snag to its use is, of course, the risk of taint, but so little applied immediately after blossom is unlikely to taint the fruit and those who have tried this treatment so far have noticed none. A more important risk is that red spider will build up after use of BHC owing to the killing of predators, but it is probable that it will wipe out Apple Sawfly so efficiently that this spray will not be needed every year.

Recommendations.

Under conditions where nicotine has consistently given good control of sawfly there is no reason to change from the usual 8 oz. of nicotine per 100 gallons at petal-fall (i.e. when 80 per cent of the petals have fallen). If sawfly has not been readily controlled by nicotine, use BHC at 1 lb. per 100 gallons when blossoming is complete (i.e. about a week after petal-fall stage). If the infestation is expected to be heavy, BHC at 2 lb. may be used, but liquid derris may be needed in early June to check the build-up to Red Spider. It is essential to add a wetter to ensure that the insecticide gets right into the calyx-cup of each flower.

Summary.

Attention is drawn to the excellent control of Apple Sawfly obtained with BHC and tentative recommendations for its use are given.

AN IMPORTANT NEW TYPE OF WETTER

By A. H. M. KIRBY

In some circumstances a wetting agent can improve the performance of a spray by making it cover a given surface more completely and penetrate into crevices but it can also lead to more run-off and may make the deposits more easily removed by rain. Therefore a wetter should be used only where it is known to be advantageous, as for instance in spraying for Apple Sawfly control.

There are many efficient wetting agents on the market but recently an entirely new type has become available in this country. It is one of a series developed in America, and chemically it is dioctyl sodium sulphosuccinate.* It has little value as an emulsifying agent but, besides being available in very pure form and also being soluble in most organic solvents as well as in water, it has several other assets. It maintains its effectiveness in very dilute solutions and is equally efficient in both hard and soft waters, although not recommended where very alkaline solutions are involved. It is odourless and stable to temperatures well above the boiling-point of water. Moreover, it appears to be non-toxic to human beings whether used internally or externally.

The efficiency of this wetting agent can be judged from comparison with the well-known wetting agent, sodium lauryl sulphate, by means of the " Draves test ", which determines the time required for a standard textile to sink in an aqueous solution of the wetting agent. At a concentration of 0·05 per cent, the relative times for these two agents were 8 seconds and 47 seconds respectively ; even at 0·02 per cent only 26 seconds were required for the new agent. The relative efficiency of this new material compared with sodium lauryl sulphate is roughly 5 : 1, and similar or better ratios have been obtained for a number of competitive wetters.

The new wetter is exceptionally cheap to use because of its efficiency at low dilutions. We do not recommend using it at concentrations exceeding 0·01 per cent because this will give as good wetting as is needed, and higher concentrations will lead to excessive frothing in the spray tank.

At present this wetter can be bought in two forms. Both are solutions in water plus methylated spirit, one contains 60 per cent of the chemical and the other 20 per cent. The stronger concentrate works out cheaper to buy and also takes up less room in storage than the weaker one, but the latter can be poured straight into the spray tank, whereas the 60 per cent stuff requires pre-dilution in a bucket, which takes time.

This new wetter has been used in formulating insecticides and acaricides for our laboratory and field trials for several years and we believe that it will prove valuable for commercial spraying where an efficient wetting agent is desirable.

Summary.

A new type of wetter is described, and suggestions are made for its use in fruit sprays.

* At present the only form available is known as Aerosol OT.

INDEX

Abscission, 30
Acaricides, 42, 45
————, toxicity, 164
Amos Black black currant, 20, 25
—— Memorial lecture, 53
Analytical methods for elements in plants, 34, 122, 124
Anatomical studies, 21
Anti-frost screens, 60
Aphids, biological studies, 42, 43
———, vectors of raspberry viruses, 50, 203
———, vectors of strawberry viruses, 43
——— of *Ribes*, 43
Apple(s), anti-frost screens, 62
——— aphids, biology and control, 42
——— Aphid, Green, 145
———, biennial bearing studies, 23, 36
——— Black Rot, 40, 137
———, blossom thinning by sprays, 23, 31
———, ——— sprinkling, 24
——— Blossom Weevil control, 18, 42
———, breeding, 24
———, Brown Rot disease, 40
———, ——— —, hail damage, 131
——— Canker, 40
——— Capsid Bug control, 18
——— Clearwing, 143
———, Codling Moth, life cycle and control, 18, 40, 43
——— cordons, pruning and rootstock trial, 24
——— cropping, 15
——— flowers, frost damage and growth promoting substances, 65
——— ———, defoliation by sprays, 23
———, fruit thinning, 23
———, June drop, 30, 111
———, incompatibility, 21
———, intensive culture, 24
———, late-flowering, 24
——— –, Leaf Spot, 40, 137
——— leaves, red spider damage, 152
———, Lord Lambourne, Rubbery Wood disease, 39
——— Mildew, 20
——— Mosaic, 39
——— –, new varieties, 20
———, pruning, 23, 24
———, Red Spider, 42
——— rootstock, Crab C, propagation, 22, 30, 116
——— rootstocks, influence on spray damage, 132
——— ——— as host for fungicide testing, 40
——— ——— –, cordons, 24
———, ———, long-term-trials, 21
——— ———, present position, 195
——— ———, propagation, 19
——— ———, Woolly Aphid control, 42
——— ———, Woolly Aphid resistant, 19
———, Rubbery Wood disease, 39
——— Sawfly, 18, 42, 45, 144
——— ——— control, 42, 144, 213
——— seedlings, very young, grafting, 71
——— ———, resistance to Woolly Aphid, 42
——— Scab, 38, 40
——— Scab control, 18, 38, 45
——— shoots, hormones and inhibitors in, 36
———, spray damage, control, 32
———, ——— ———, rootstock influence, 132
———, spray treatment, 18
———, sprays to control fruit drop, 29, 30, 108, 111
———, straw mulch, 22
———, Tydeman's Early Worcester, 24
———, ——— Late Orange, 24
Apple(s) varieties, new, 24
——— ———, breeding, 24
——— ———, effect of pollen on development, 24
——— ———, Woolly Aphid resistant, 24
———, virus diseases, 39
———, weedkillers, 22
Apricot, Bacterial Canker, 38
———, rootstock trial, 22, 24
———, variety collection, 24
Arable crop, acreage and cropping, 18
Arc method of spectrochemical analysis, 35
Auxins, 32

Bacterial Canker, 18, 38
Beneficial insects, effect of sprays on, 42, 145
Benzene hexachloride as an insecticide, 18, 43, 144, 145, 212, 213
——— ———, effect on beneficial insects, 42, 213
Biennial bearing, 23
——— ———, analytical determination of elements, 36
Biometrics, 29
Boron, estimation in plants, 34
Black currant(s), breeding, 25
—— ———, cropping, 16, 25
—— ———, cultural and manurial trials, 26
—— ——— Gall Mite, 18
—— ——— Leaf Midge, 18, 43
—— ———, new variety, Amos Black, 20, 25
—— ———, spray treatment, 18
—— ———, straw mulch, 26
—— ———, variety trial, 25
—— ———, virus diseases, 39
Black Rot of apple, 40, 137
Blepharidopterus angulatus, 151
Blossom periods, 90
——— thinning by sprays, 23, 31
Bradbourne, terraced island, 22, 30, 36
Breeding, tree fruits, 24
———, small fruits, 25
Brompton stock, propagation by cuttings, 22, 30
Brown Rot disease, 40
——— ——, apples, hail damage, 131
Bud Moth, 143
— sport in Royal Sovereign strawberry, 25

Calcium, estimation in plants, 34, 122
Calibration trials, 29
Cane Midge of raspberry, 18, 211
—— nurseries for raspberries, 204
—— Spot of raspberry, 50
—— Spot of loganberry, 18
Canning tests, raspberries, 51, 205, 208
Capsid control by DDT, 18
Caterpillar control by DDT, 18, 42
Cereals, acreage and cropping, 19
Chemical analytical methods, 34, 36
——— sprays, use of for defoliation and blossom thinning, 23, 31
Cherry(ies) Bacterial Canker, 18, 38
———, cropping, 16
———, double-working, 22
———, fruit size, estimation of, 93
———, fruit splitting, 32
———, incompatibility, 21, 22
———, propagation, 21, 199
———, rootstocks, 21
———, ———, present position, 199
———, spray treatment, 18
———, virus diseases, 39, 209

Chimera in Royal Sovereign strawberry, 25
Chromatography, 35, 36
Clay-coloured Weevil, 141
Codling Moth, 40, 142
——— ———, life cycle and control, 18, 43
——— ——, zinc fluoroarsenate trials, 45, 160
Colloidal copper, 18
Compatibility of rootstock and scion, 21, 22
Concentrated dip method of applying growth substances, 116
Cordons, pruning and rootstock trial, 24
Cover cropping, 22
—— ———, analytical determinations of elements, 36
Crab C apple rootstock, 22, 30, 116
Crotch angles, control by growth substances, 30, 76
Cuprous oxide, 18
Cuttings, hardwood, 22, 30
———, ———, treatment with growth substances, 116
———, ———, trial with Nursery Research Station, Boskoop, 30
———, softwood, 30

DCPA as a weedkiller, 26
DDT as an insecticide, 18, 42, 43, 45, 143, 145
——, effect on beneficial insects, 42
Deficiencies, mineral, general work, 34
Defoliation, for control of biennial bearing, 23
Derris, 18, 42, 145
Design of experiments, 28, 29
Diphenyl sulphone as an insecticide, 43
Dispersal of Red Spider Mite, 42, 147, 155
Dispersible sulphur, 18, 45
DNC, as a weedkiller, 22, 26
—— sprays, 18, 42
—— sprays, for blossom thinning, 31
Double-working, pears, 22
———, sweet cherries, 22
Drop of fruit, June drop, 30, 111
—— — ——, pre-harvest, 31, 108

Early Worcester apple, 24
Elements, distribution of in buds, 36
———, in plants, estimation of, 34, 122, 124
Estimation of insect population, 42, 148
——— of trace elements, 34, 122, 124
Experimental design, 28, 29
——— ———, calibration trials, 29
——— nurseries, 19
——— orchards, 15
External contacts, 48

Fertilizers, inorganic, 22
Field experimental design, 28
Fractionation of nutrient elements, 35
——— — plant extracts, 35
Flame method of spectrographic analysis, 34
Fresh plantings, 17
Frost damage investigations, 23, 24, 26, 60, 65
—— ——— ———, effect of anti-frost screens on air temperatures, 60
—— ——— ———, effect of straw mulches, 26
—— ———, raspberries, 51
—— ———, wall effect, 61
Fruit drop, 30, 108, 111
—— ——, rain and control by sprays, 108
—— marketing, 17
—— plants, organic constituents, 35
—— size, cherries, estimation of, 93
—— splitting, cherries and plums, 32
—— Surface-eating Tortrix, 143
—— tree and its environment, 53
—— —— rootstocks, research, 193
—— Tree Red Spider Mite, 42, 147
Fruit Tree Red Spider Mite, control, 18, 42, 46
—— — — ——— ——, damage, 42
—— — — ——— ——, ——— to apple leaves, 152
—— — — ——— ——, dispersal, 42, 147, 155
—— — — ——— ——, life history, 42
—— — — ——— ——, literature, 42
—— — — ——— ——, predators, 42, 151, 158
—— — — ——— ——, systematic study, 43
Fungicide(s) field trials, 45
——— studies, 40, 45
———, use of rootstocks for testing, 40
Fungistatic activity of certain organophosphorus insecticides, 172

Gage plums, cropping, 24
Gall Mites, systematic studies, 43
Gammexane, *see* benzene hexachloride
Gooseberry breeding, spineless varieties, 25
———, virus diseases, 39
Grading and packing fruit, 17
Graft transmission of Rubbery Wood disease, 39
——— unions, 29
Grafting, very young apple seedlings, 71
Grassing down, 22
Green Apple Aphid, 145
Growth substances, aid in propagation of cuttings, 22, 30, 116
——— ———, concentrated dip, 116
——— ——— and frost damage, 24, 65
——— ———, after effect on storage quality, 31
——— ———, effect on pollen, 32
——— ———, sprays to control fruit drop, 30, 31, 108, 111
——— ———, sprays to control fruit drop, effect of rain on, 31, 108
——— ———, sprays to control fruit drop, effect of season and date of spraying, 111
——— ——— to widen crotch angles, 30, 76
——— ——— as weedkillers, 22, 26
Grubbing of old plantations, 17

Hail damage and Brown Rot, 131
Hawthorn Leaf Miner, 144
Hessian as anti-frost screen, 61
Histological investigations, 21
Hop-Damson Aphid, 146
Hop(s), ease of picking, classification according to, 187
——— Mosaic, 40
——— Nettlehead, 40
———, new varieties, ease of picking, 187
———, propagation trials, 190
———, Red Spider, 147
——— Root Weevil, 141
——— seed, treatment to improve germination, 139
——— Split Leaf Blotch, 40
——— Sets from strap-cuts, 190
——— Verticillium Wilt, 38
——— ——— ———, nutrient effects on, 39
——— ——— ———, varieties resistant to, 38
———, virus diseases, 40
Hormone(s) activity, method for estimating, 32
——— relations in fruit trees, 32
——— ——— in apple shoots, 36
Host resistance to Verticillium Wilt, 38

Inarching, young apple seedlings, 72, 73
Incompatible graft combinations, 21
Incompatibility, apples, 21
———, cherries, 21, 22
———, pear on quince, 21,
———, peaches, 21
———, plums, 21

Injection, for diagnosis and cure of mineral deficiencies, 36
Inorganic fertilizers, 22
Insect populations, estimation of, 42, 148
——— ——————— of strawberry, 43
——— vectors of virus diseases, 40, 43, 50, 203
Insecticides, field trials, 45
———————, mechanism of action, 44
———————, penetration, 177
———————, studies, 44
———————, synthetic, for control of Sawfly, 213
Intensive culture of apples and pears, 24
Iron, estimation in plants, 34, 124
Iron deficiency, efforts to cure, 36

June drop, control of, 30, 111
Juvenile period, methods of shortening, 22, 24, 71

Late Orange apple, 24
Lead arsenate and lime sulphur, 160
——— ———————, as an insecticide, 45, 145, 160
Leaf damage by Red Spider Mite, 152
——— drop, 30
——— Miner, Hawthorn, 144
——— Spot of apple, 40, 137
Leys, 22
Lesser Yellow Underwing, 142
Liaison work, 48
Lime-sulphur, 18, 20, 42, 43, 45
——————— and lead arsenate, 160
——————— atomised, 40, 50
Loganberry(ies), Cane Spot, 18
———————, cropping, 16
———————, manurial and training trial, 26
———————, Raspberry Beetle, 18
———————, spray treatment, 18
Long-horned Beetle, 141

Magnesium, estimation in plants, 34
Manganese deficiency studies, 36
———————, estimation in plants, 34
Manuring, blackcurrants, 26
———————, loganberries, 26
Marketing of fruit, 17
Mass Spectrometer, 35
MCPA as a weedkiller, 26
Mercurated lead arsenate, 18
Meterological observations during 1950, 92
Meteorology, 26, 90
———————, new crop weather station, 26, 91
Methyl bromide, as control for Tarsonemid Mite, 43
Micro-chemical tests for starch content, 21
Mineral deficiencies in Bradbourne lake-bed, 36
——— ———————, general work on, 34
——— nutrients of plant, 35
Mites, 43
Morello cherries, blossom wilt and leaf spot, 38
Mosaic disease of hops, 40
Mycorrhiza, 21
Myrobalan B, propagation by cuttings, 30, 116

Netting as anti-frost screen, 60
Nettlehead disease of hops, 40
New plantings, 17
Nicotine as an insecticide, 18, 42, 45, 145, 213
Nursery work, mechanical aids, 201
Nut(s), Brown Rot, control, 40
———, cropping of walnuts, 26
——— Weevil, 42
Nutritional studies, 36

Oat-apple Aphid, 146
Organic constituents of fruit plants, 35
Organophosphorus insecticides, fungistatic activity, 172
Ovicides, mechanism of action, 44
———, penetration, 177

Packing and grading fruit, 17, 49
Packing shed organization, 17
Parathion as an insecticide, 18, 42, 43, 45, 145
Peach(es), incompatibility, 21
———, Potato Aphid, 146
———, pruning, 23
———, rootstocks, 22, 24
———, spray treatment, 18
——— varieties, 24
Pear(s), Aleyrodes, 146
——— and Cherry Slugworm, 145
———, breeding, 24
———, cropping, 15
———, double-working, 22
———, incompatibility, 21, 22
———, rootstock trials, 21
———, rootstocks, present position, 197
——— Sawfly, 42, 145, 147
——— Scab, 38, 40, 46
——— Scab control, 18
———, spray treatment, 18
———, virus diseases, 39
Peas, acreage and cropping, 19
Phenyl mercury chloride for Apple Scab control, 45
Phosphorus, estimation in plants, 34
Physiology of growth and form, 30
Phytotoxicity trials, 42, 47
Plant(s) analysis methods, 34, 122, 124
——— breeding, 24
———, estimation of elements in, 34, 122, 124
———, injection methods, 36
———, nutrient elements, fractionation of, 35
———, organic constituents, 35
Plantings fresh, 17
Plum(s), Bacterial Canker, 18
———, control of crotch angles by growth substances, 30, 76
———, cropping, 16, 24
———, fruit splitting, 32
———, incompatibility, 21
———, pruning, 23
——— rootstock(s), anatomical studies, 21
——— ———————, present position, 198
——— ———————, propagation from hardwood cuttings, 22, 30, 116
——— ———————, trials, 21
———, spray treatment, 18
———, varieties, 24
———, virus diseases, 39
Pollen, effect of growth substances on, 32
———, effect of from different varieties, 24
Potassium sulphate spray, effect on fruit drop, 31
Potatoes, acreage and cropping, 19
Predaceous insects of Fruit Tree Red Spider, 42, 151, 158
——————— ———, effect of sprays on, 42
——————— mites on fruit trees, 43
Pre-harvest fruit drop, rain and control of by sprays, 108
Propagation of fruit trees, 22
——————— hops, 190
——————— rootstocks, 19, 21, 22, 30, 116, 194
——————— raspberries, 51, 204
——————— strawberries, 19, 25
Pruning, 23, 24, 30
Pyrethrum as an insecticide, 145, 149

Quick freezing, raspberries, 205, 208

Rabbit repellents, 25, 87
Raspberry(ies) aphids, as vectors of virus diseases, 50, 203
——————— Beetle, 18
———————, breeding, 25
——————— Cane Midge, 18, 211
——————— cane nurseries, 204

Raspberry(ies) Cane Spot, 50
————, canning tests, 51, 205, 208
————, cropping, 16, 25, 51
———— diseases, investigations in Scotland, 50, 203
————, frost damage, 51
————, nuclear stock propagation, 51
————, planting stocks, 203
————, propagation of cane, 204
————, quick freezing tests, 205, 208
———— in Scotland, 203
————, spray treatment, 18
————, stock testing, 50
————, straw mulch, 26
———— varieties, 25, 51, 204
————, virus diseases, 39, 50, 127, 203
————, weedkillers, 26
Record office, 28
Red Bud Borer, 43
Red Spider, Fruit Tree, 42, 147
—— ————, ———— ————, control, 18, 42, 46
—— ————, ———— ————, damage, 42
—— ————, ———— ————, ———— to apple leaves, 152
—— ————, ———— ————, dispersal, 42, 147, 155
—— ————, ———— ————, life history, 42
—— ————, ———— ————, literature, 42
—— ————, ———— ————, predators of, 42, 151, 158
—— ————, ———— ————, systematic study, 43
—— ————, Hop, 147
—— ————, Strawberry, 147
Ribes aphids, 43
Root and green crops, acreage, 18
Rootstock(s), anatomical studies, 21
———— as host for fungicide testing, 40
————, influence on spray damage in apple, 132
———— trials, 21, 24
————, new varieties, 19
————, propagation, 19, 21, 22, 30, 116, 195
————, research on, 193
————, seedling, 193
————, Woolly Aphid resistant, 19
Routine spraying programme, 18
Rubbery Wood disease of Lord Lambourne apple, 39

Sampling methods, 29
———— ————, estimation of fruit size of cherries by, 93
Sawfly, 18, 42, 45, 144, 145, 147, 213
Schradan, 18
Seedlings, grafting young apples, 71
Shedding of fruits, blossoms and leaves, 30
Shot-hole Beetle, 141
Slugworm, Pear and Cherry, 145
Small fruits, cropping, 16, 51
———— ————, frost investigations, 26
———— ————, insect studies, 43
———— ————, straw mulch and frost damage, 26
———— ————, variety and strain trials, 25
———— ————, virus diseases, 39
Sodium chlorate as a weed killer, 22
Soil management, 22
—— moisture, 22
—— studies, 22
—— temperature in orchards, 22
—— uniformity, restoration of, 23, 29
Spacing for strawberries, 26
Spectrographic analysis of plant material, 34, 36
Split Leaf Blotch disease of hops, 40
Spray damage, 32, 42, 47
———— ————, influence of rootstock in apple, 132
Spraying, application methods, 40
———— for cure of mineral deficiencies, 36
———— for defoliation and blossom thinning, 23, 31
Spraying programme, 18
———— to reduce fruit drop, 30, 31, 108, 111
Sprinkling with water for frost control, 24
Spurs, life history studies, 23
Statistical studies, strawberry crop and vigour measurements, 100
———— technique, 28
Statistics and Records Section, work of, 28
Stem Eelworm, 43
Stock/scion compatibility, 21, 22
———— relationship, 30
Stool-beds, 19, 20
Storage behaviour of apples after growth substance sprays, 31
Strawberry(ies) Aphid, life history and control, 18, 43
———— Black Root Rot, 43
————, breeding, 25
————, bud sport, 25
————, Cauliflower Disease, 40, 43
————, cropping, 16
————, cropping trials, arrangement of plots and blocks, 100
————, ————, statistical studies, 100
————, ————, spread measurements, interpretation, 105
————, cultural trials, 26
————, dust treatment, 18
———— Eelworm, 40, 43
———— experiments, calibration, 29
————, fauna, 43
———— insects, 43
———— Mildew, 18
————, mycorrhiza, 21
————, propagation, 19, 25
———— Red Spider, 147
———— runners, production of, 19
————, spacing, 26
————, spray treatment, 18
———— Tarsonemid Mite, 43
———— variety trials, 25
————, variant form of Royal Sovereign, 25
———— vigour measurements, statistical studies, 100
————, virus diseases, 39
————, weedkillers, 26
———— Weevil, 18
Straw mulch, 22, 26
—— ———— and frost damage, 26
String netting as anti-frost screen, 60

Tar Oil spray, 18
Tarsonemid Mite of strawberry, 43
Thinning of blossoms, 23, 31
———— fruits, 23
Top fruits, cropping, 15
Tortricids, 43
Tortrix control, 42
————, Fruit-Surface-eating, 143
Trace elements, estimation, 34, 122, 124
Tree fruits, insect studies, 42
—— ————, virus diseases, 39
Tree injection, 36
Tydeman's Early Worcester apple, 24
———— Late Orange apple, 20, 24

Uniformity trials, 29

Variation studies, 29
Varieties, collections, 24
————, of walnuts, 80
Vegetative propagation, 30, 194
———— ————, rootstocks, 194
Verticillium Wilt, 38
———— —— of hops, 38

Virus diseases of apple, 39
——— ——— blackcurrant, 39
——— ——— cherry, 39, 209
——— ——— gooseberry, 39
——— ——— hops, 40
——— ——— pear, 39
——— ——— plum, 39
——— ——— raspberries, 39, 50, 127, 203
——— ——— strawberries, 39
——— ——— tree fruits, 39

Walnut(s), cropping, 26
———, varieties, 80
Water sprinkling for frost control, 24
Weather conditions during 1950, 15, 19, 90
Weedkillers, 22, 26
Wetting Agents, 44, 214
Winter Moth control, 42
Wood Leopard Moth, 142
Woolly Aphid, 145
——— ——— Parasite, 145
——— ———, rootstocks resistant to, 19, 42
——— ———, varieties resistant to, 24
Wounds, avoidance for Brown Rot prevention, 40

Zinc, estimation in plants, 34
—— fluoroarsenate, trials against Codling, 45, 160